

NRA  
TIM #4



# **Technologies Enabling All-Weather Maximum Capacity by 2020**

## Self Assessment Results

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Presented at NASA Ames Research Center

Moffett Field, CA

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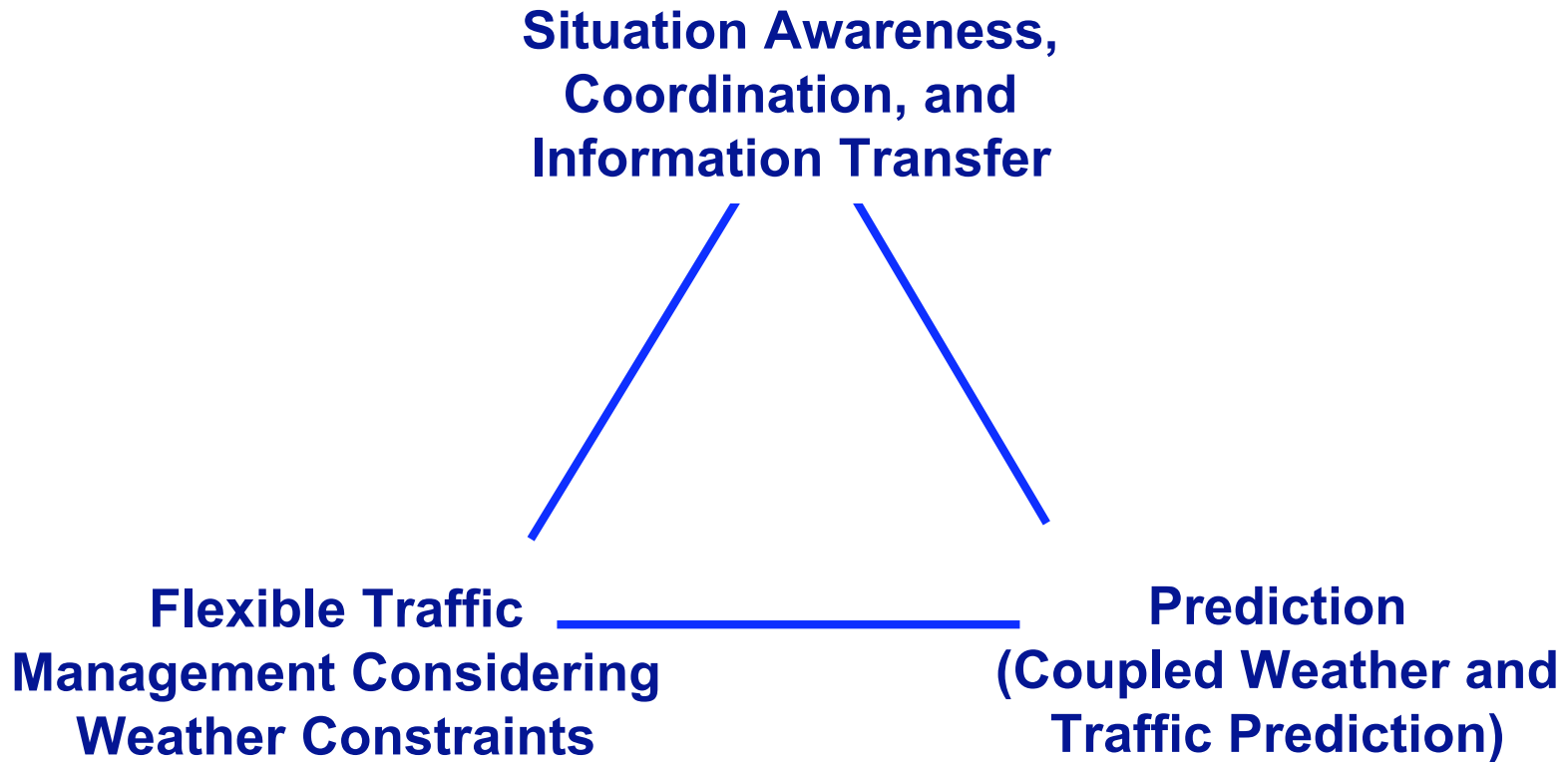
## Agenda:

- Vision
- Core Ideas
- Anticipated Benefits
- Approach to Self Assessment
- Metrics
- Results for Self Assessment
- Challenges Ahead
- Conclusions

## Vision:

- Provide an innovative, gate-to-gate solution to predicting and minimizing the effects of weather on National Airspace System (NAS) performance, working toward all-weather **Maximum Gate-to-Gate Capacity** by 2020.

## Core Idea Triad:



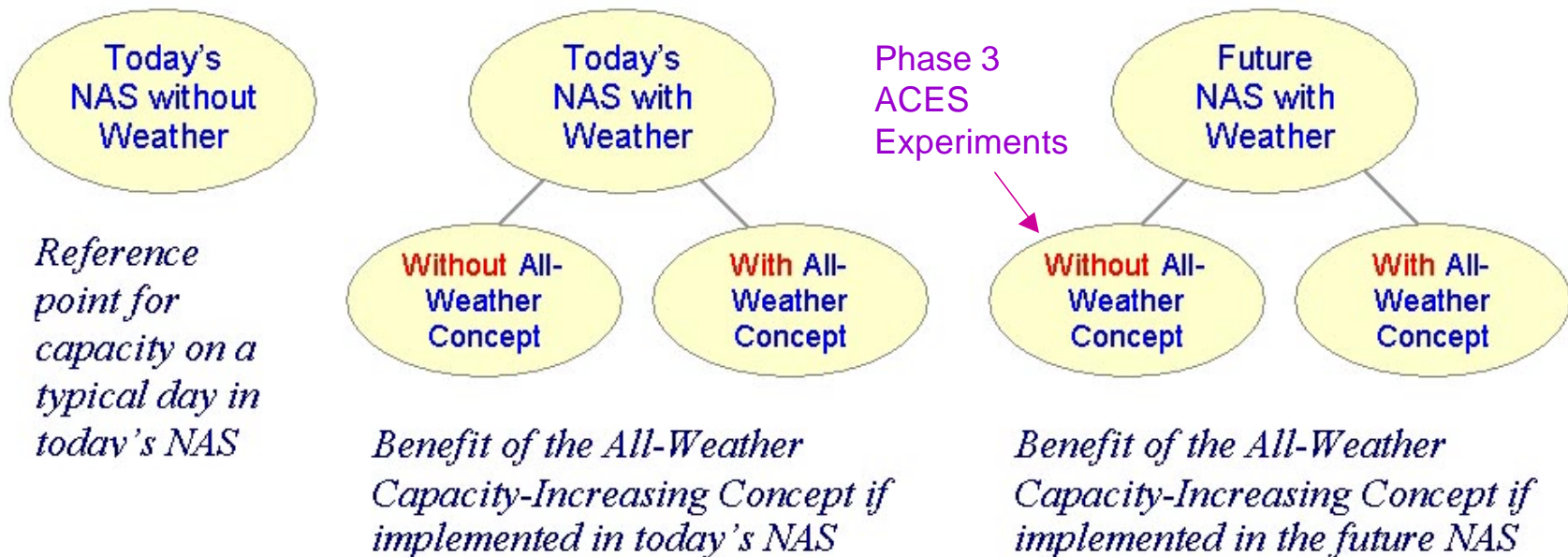
## Anticipated Benefits:

- More **Accurate Take Off Times** due to constraint management, better weather information and predictions, and EDCT compliance via DSTs
- Increased **Safety** due to better predictions of aircraft trajectories clear of hazardous weather
- Increased airport and en route **Throughput** through weather avoidance algorithms that dynamically adjust flows to weather constraints
- **Delay Savings** facilitated by weather constraint planning – directly benefits airline schedule integrity

## Anticipated Benefits:

- **User Preferences** included in solutions
- **Equity** enforced through user preferences and fair DST solutions
- **Human Factors benefits** from a common situation awareness and better human-computer interfaces
- **Reduced Environmental Emissions** due to reduced taxi times and fewer airborne delays and less airborne holding per flight

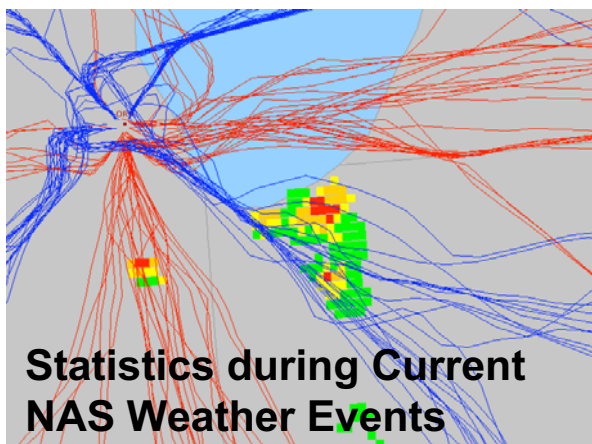
## Approach to Self Assessment:



- Investigate tradeoffs for different types of days (or ¼ hours) in the NAS
  - No Weather
  - Typical Weather
  - Severe Weather
  - Rare Weather

# Self Assessment Setup:

- **Select Domain of Interest**
  - Surface
  - Transition
  - En Route
- **Select Parameterizations**
- **Select Metrics**
- **Establish Scenarios of Interest**
- **Run Experiments**



Metric	Category
<b>Capacity</b>	Airport Capacity
	En Route Sector Capacity
	NAS Capacity
	Throughput
<b>Flexibility</b>	User Preference
	Equity
<b>Efficiency</b>	Government, Airline, & Passenger Costs
	Airspace Utilization
<b>Predictability</b>	Time Variability
	EDCT Compliance
	Sector Demand
<b>Safety</b>	Weather Exposure
	Conflict Alerts
	Workload
<b>Environment</b>	Noise
	Pollution
<b>Delay</b>	Average Delay
	Average Block Time
<b>Human Factors</b>	Human Performance
	Human Behavior
	Preference Metrics

# Weather Related Metrics:

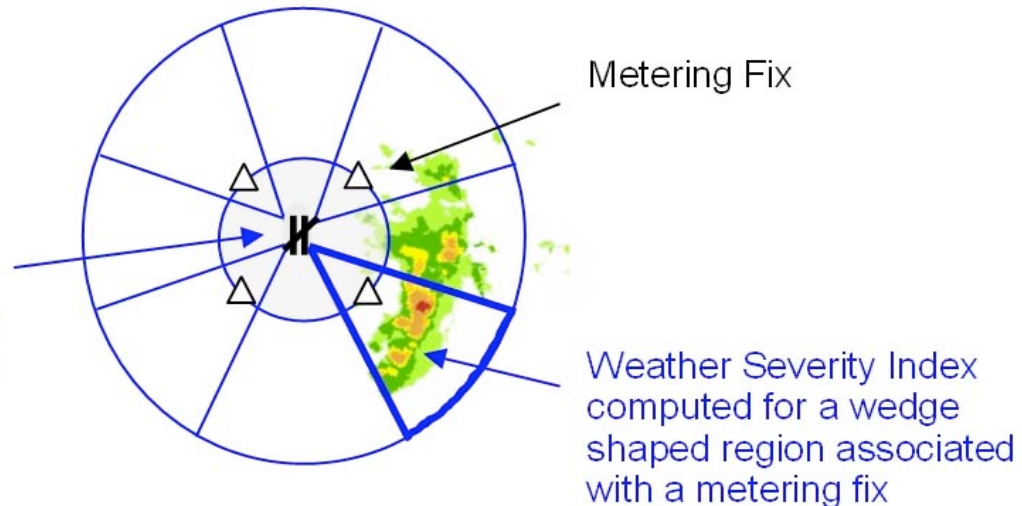
- NWS Weather Levels

NWS Level	Color	Rainfall Rate (mm/hr)	Reflectivity (dBZ)	Type
0	None	<0.49	dBZ<18	None
1	Light Green	0.49 - 2.7	18 ≤ dBZ <30	Light Mist
2	Dark Green	2.7 - 13.3	30 ≤ dBZ <41	Mod.
3	Yellow	13.3 - 27.3	41 ≤ dBZ <46	Heavy
4	Orange	27.3 - 48.6	46 ≤ dBZ <50	Very Heavy
5	Deep Orange	48.6-133.2	50 ≤ dBZ <57	Intense
6	Red	>133.2	57 ≤ dBZ	Extreme

- Airport Weather Severity Index (WSI)

$$WSI = \int_{region} wds$$

Weather Severity Index computed for a circular region around the airport up to the metering fix locations

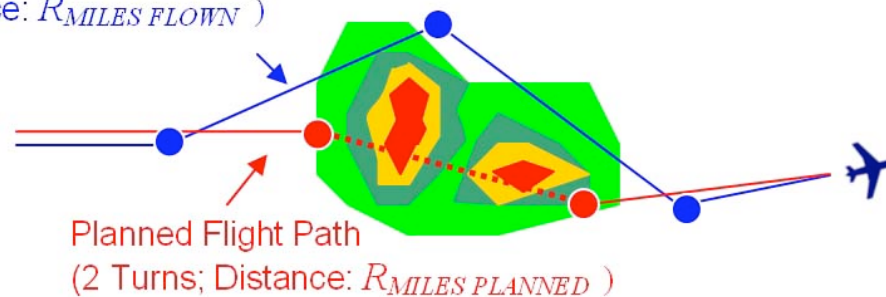


# Additional Weather Related Metrics:

- Deviation from User Preference

$$\delta R = R_{MILES\ FLOWN} - R_{MILES\ PLANNED}$$

Actual Flight Path (3 Turns;  
Distance:  $R_{MILES\ FLOWN}$  )

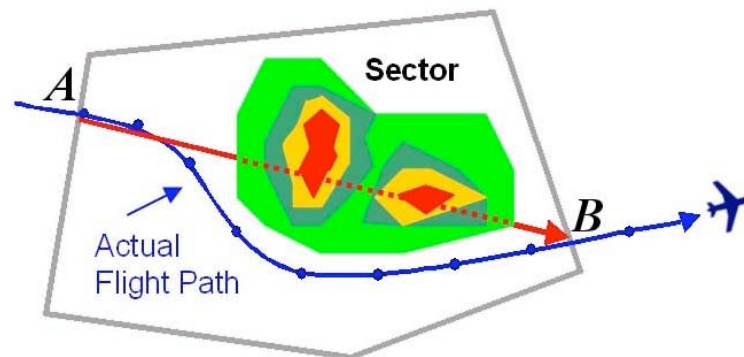


- Sector Delay due to Weather

$$S_{eff} = DirectToDist / (T_B - T_A)$$

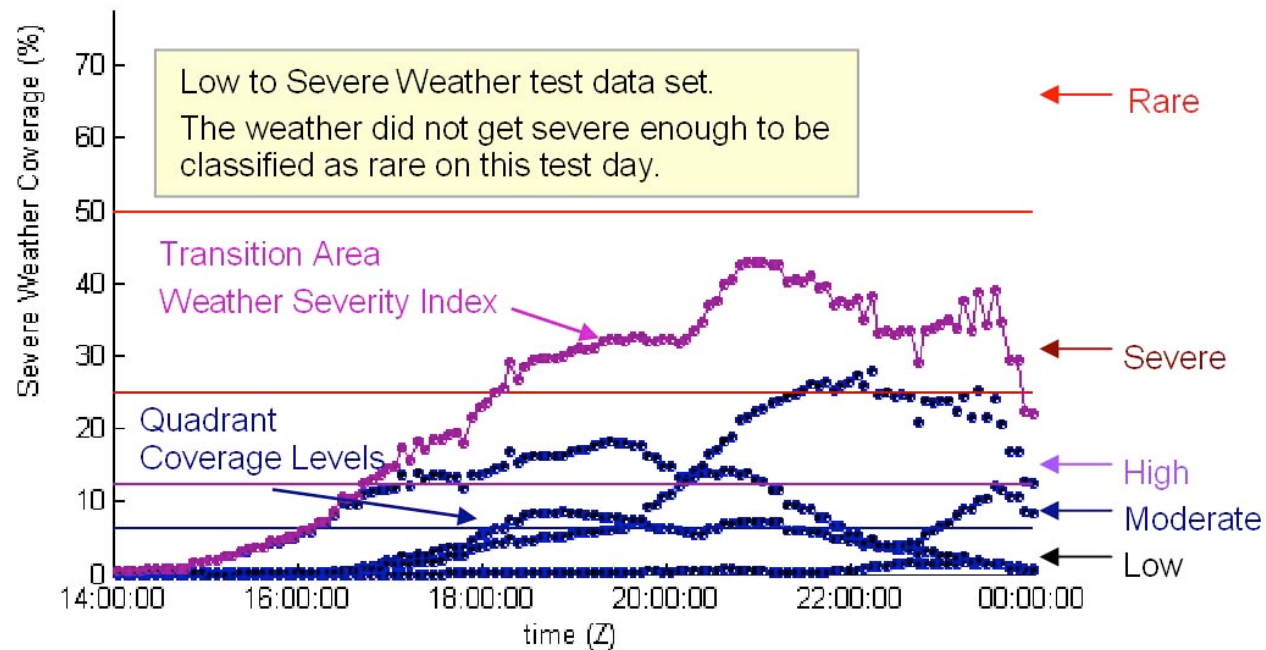
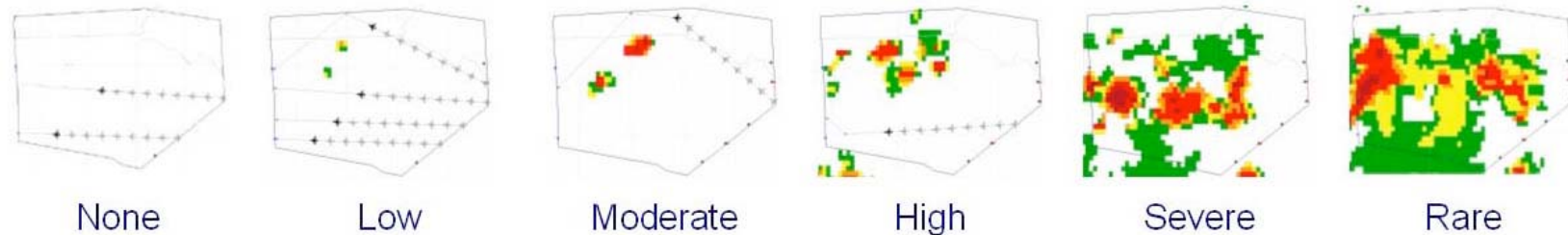
$$S_{ave} = FlownDist / (T_B - T_A)$$

$$Delay = \frac{S_{eff}}{S_{ave}} (T_B - T_A)$$



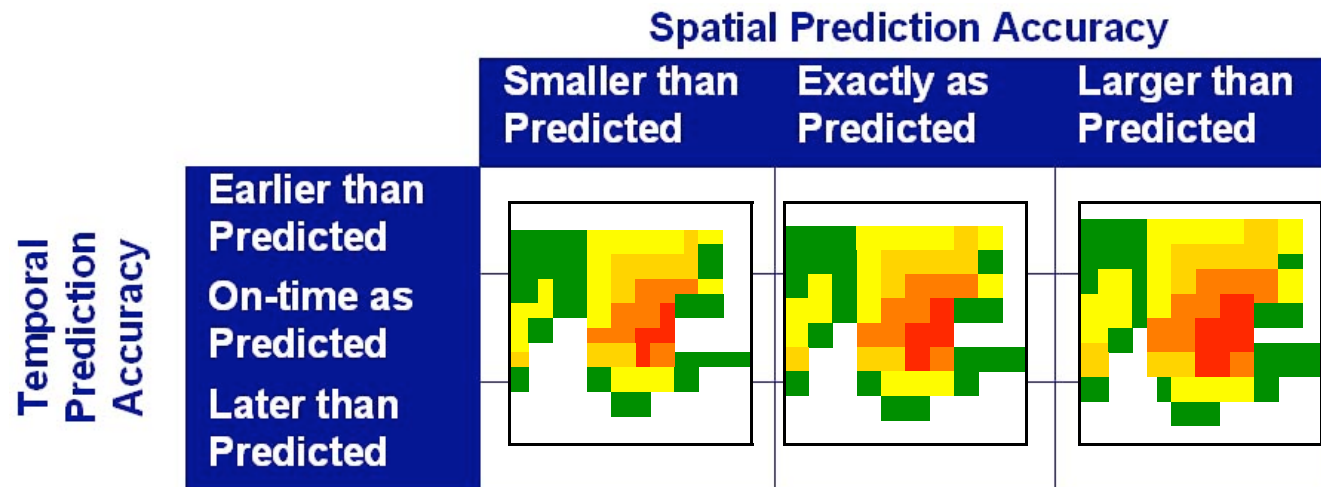
# Example Parameterizations:

- Weather Severity



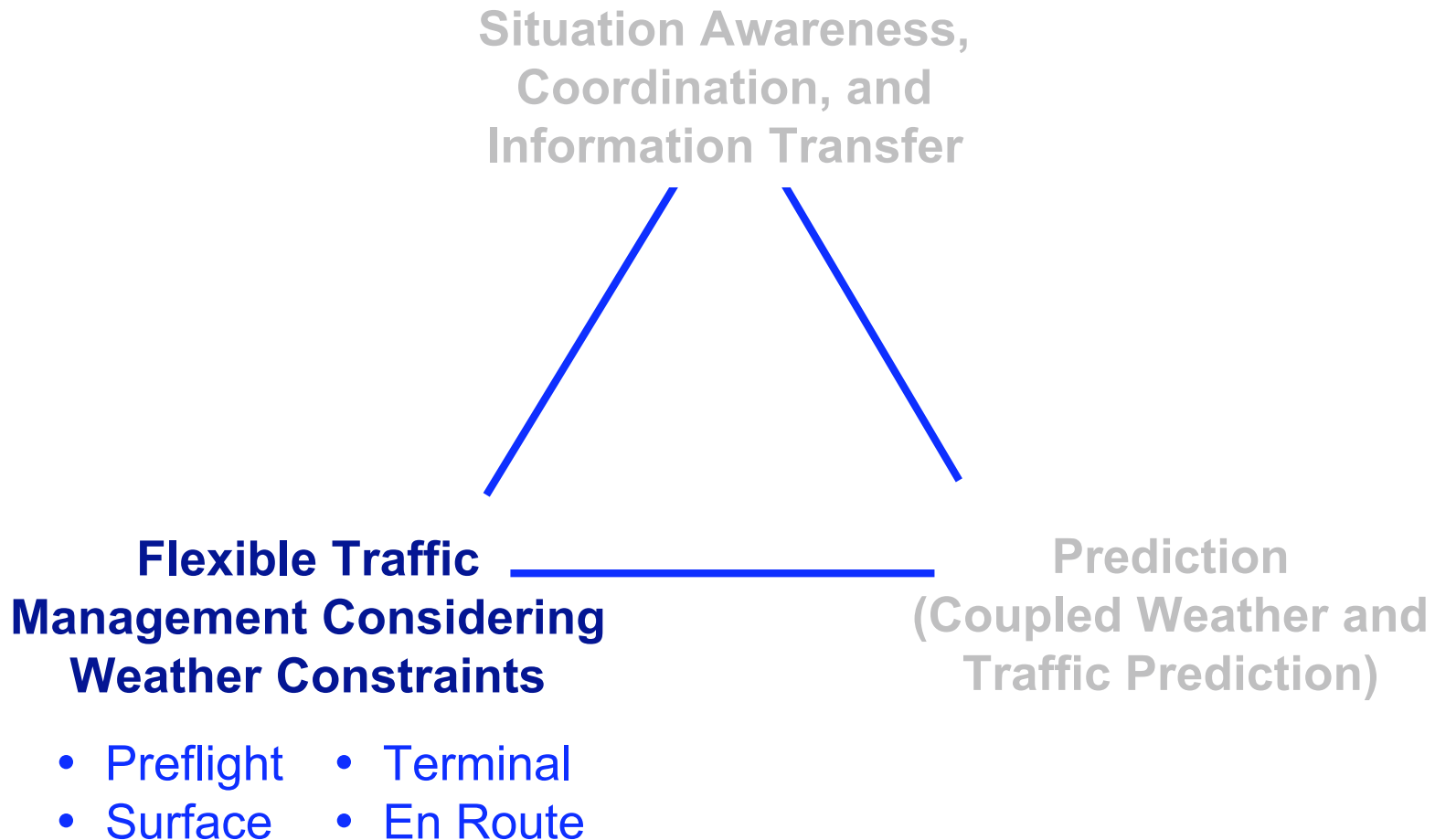
## Example Parameterizations:

- Wind Shift and Convective Weather Prediction Accuracy



- EDCT Compliance
- De-Icing Condition
  - At Gate vs At De-Icing Spot Location
  - No De-Icing vs De-Icing (Single-Stage) vs De-Icing/Anti-Icing (Two-Stage)

## Core Idea 1:

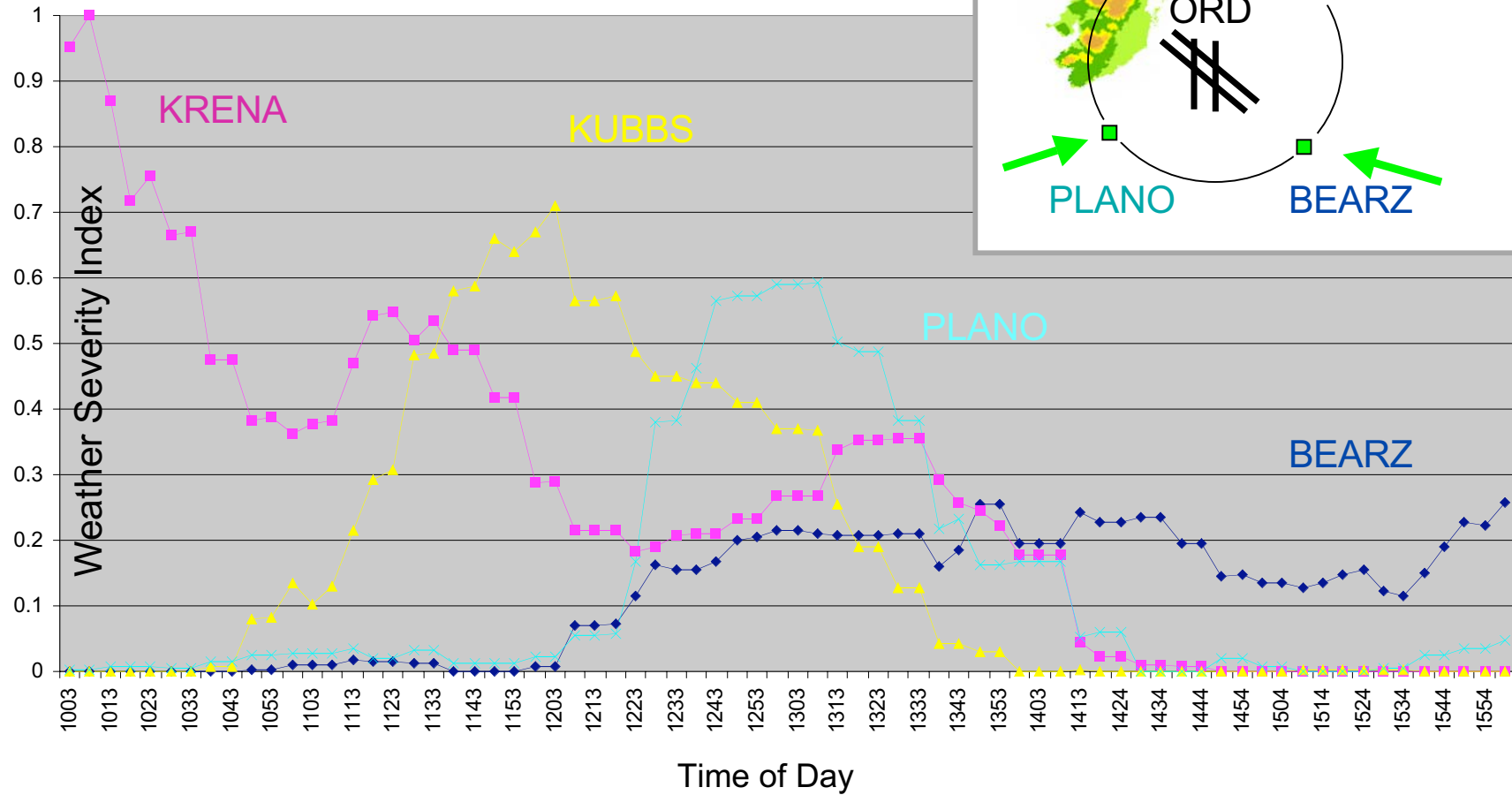
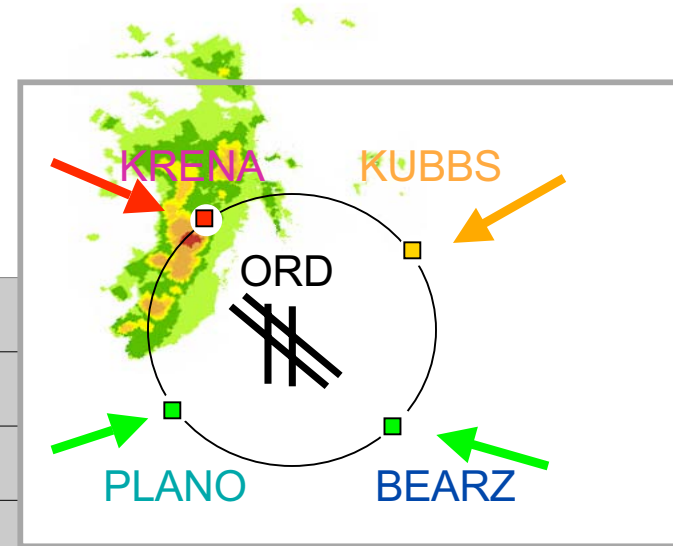


## **Core Idea 1.1: Pre-Flight Planning to Manage Airport Flow Rates**

- **Long-Term Probabilistic Weather Forecasts**
- **Airport GDPs**
- **Fix-Based GDPs (w&w/o En Route Cornerpost Swaps)**
- **Distance-Based 1<sup>st</sup> Tier, 2<sup>nd</sup> Tier GDPs**
- **Multi-Airport GDPs**
- **Cancellations**
- **User Priorities and Constraints**

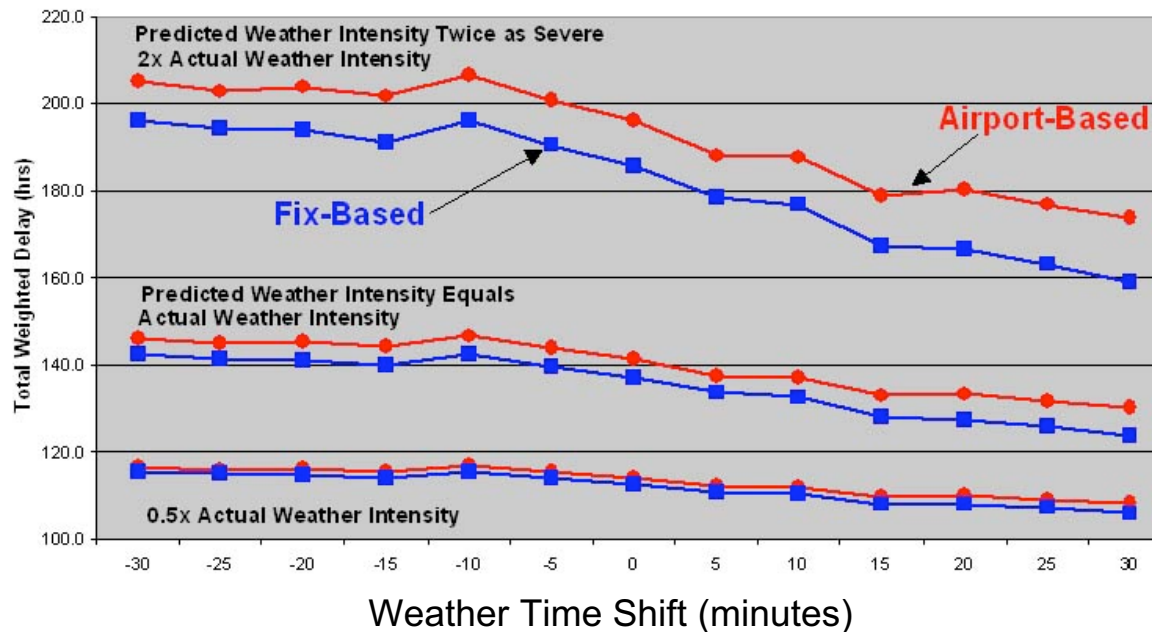
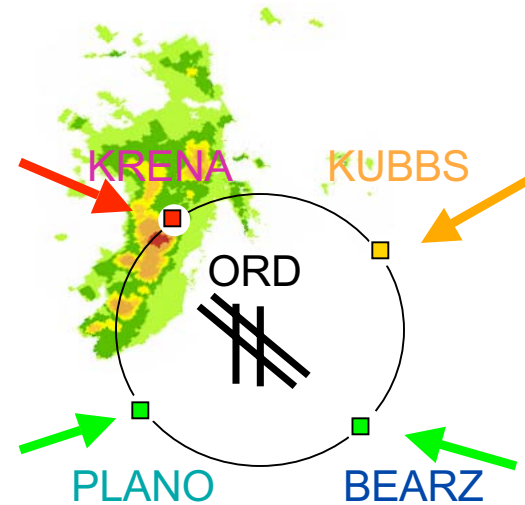
# Fix-Based GDP Analysis

26 June 2002



# Airport vs Fix-based GDPs

- What could we do with improved weather prediction accuracy and pre-flight GDPs?

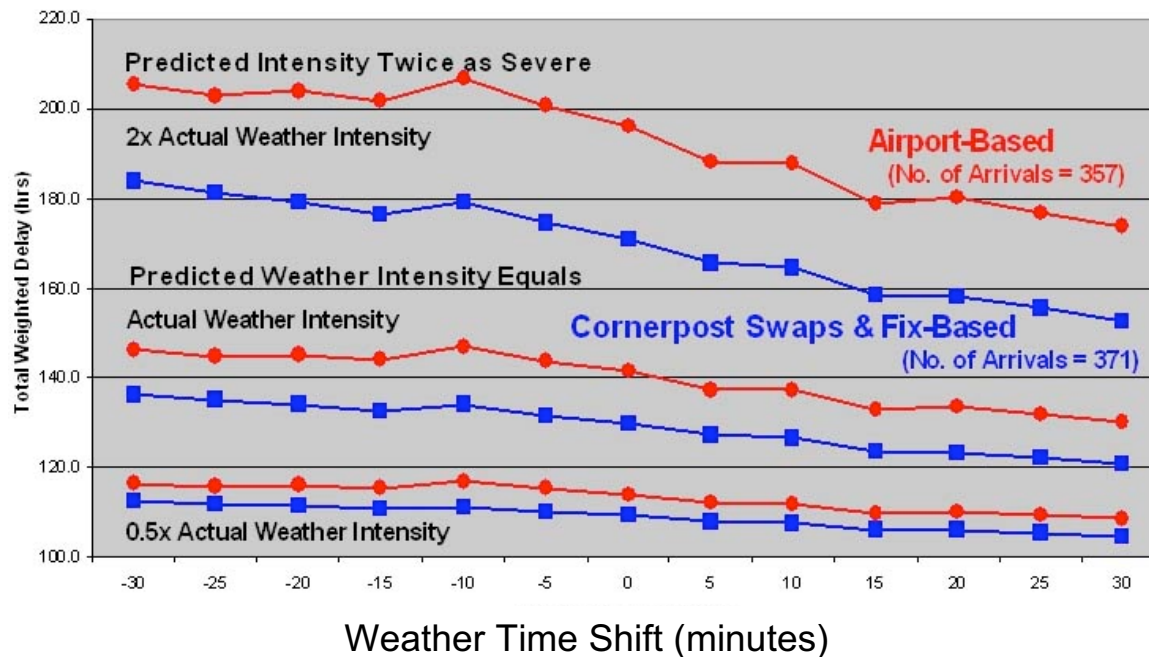
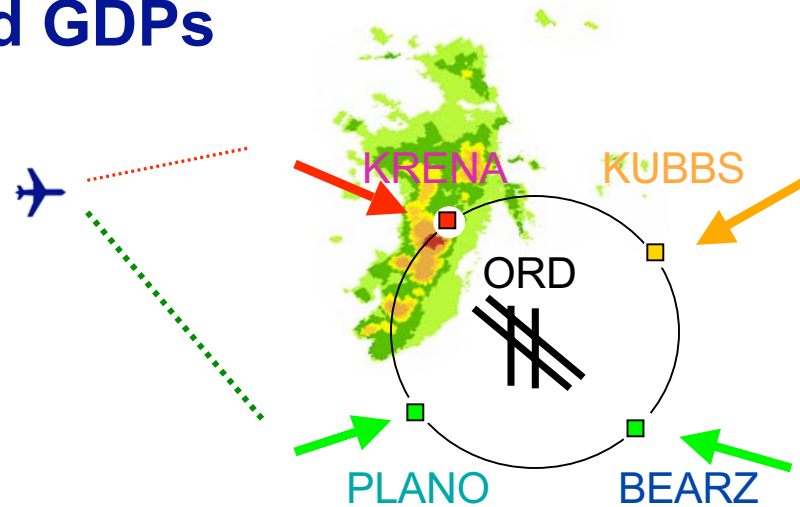


ORD simulation with weather prediction accuracy varied spatially and temporally in a controlled experiment.

A positive weather time shift denotes forecast weather later than actual weather.

# Airport GDPs vs Fix-based GDPs with Cornerpost Swaps

- What if we could plan cornerpost swaps en route during the GDP implementation?



ORD simulation with weather prediction accuracy varied spatially and temporally in a controlled experiment.

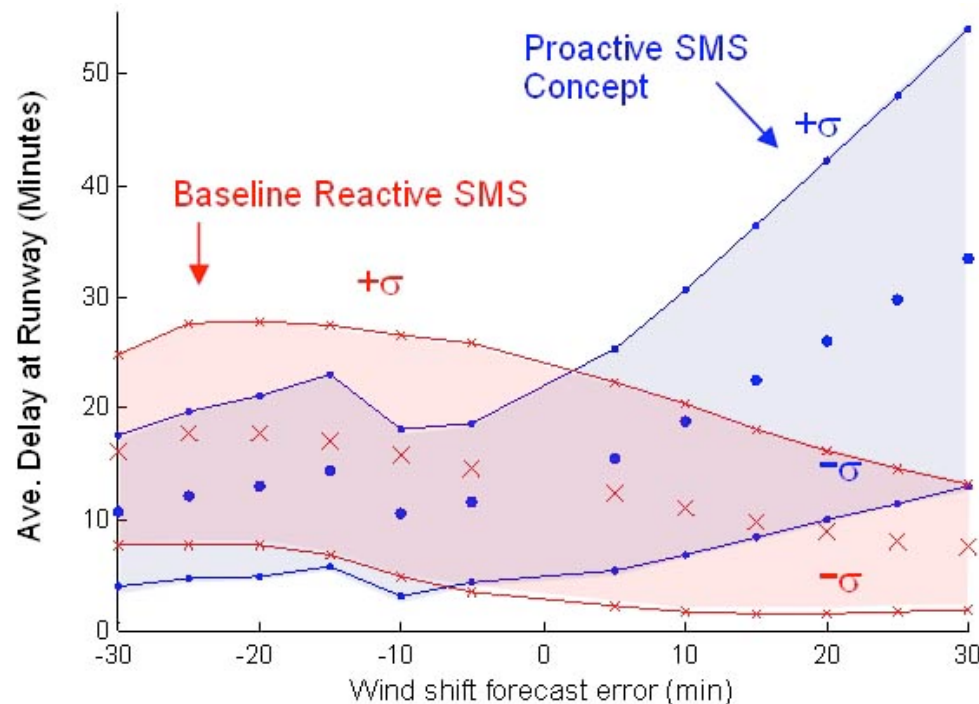
A positive weather time shift denotes forecast weather later than actual weather.

## **Core Idea 1.2: Precise Control of Take Off Time to Address Weather Constraints**

- **Passback of Terminal/Transition airspace weather constraints for departure flights**
- **Ground Stop and GDP EDCTs in support of SWAP**
- **APREQs for timing of departure releases for capping / LAADR maneuvers into overhead streams**
- **EDCT Compliance through SMS, including coordination of de-icing and snow removal vehicles on runways**
- **Augmented Reality, HUD, and EMM Displays for low and zero visibility conditions**

# SMS Planning for a Configuration Change

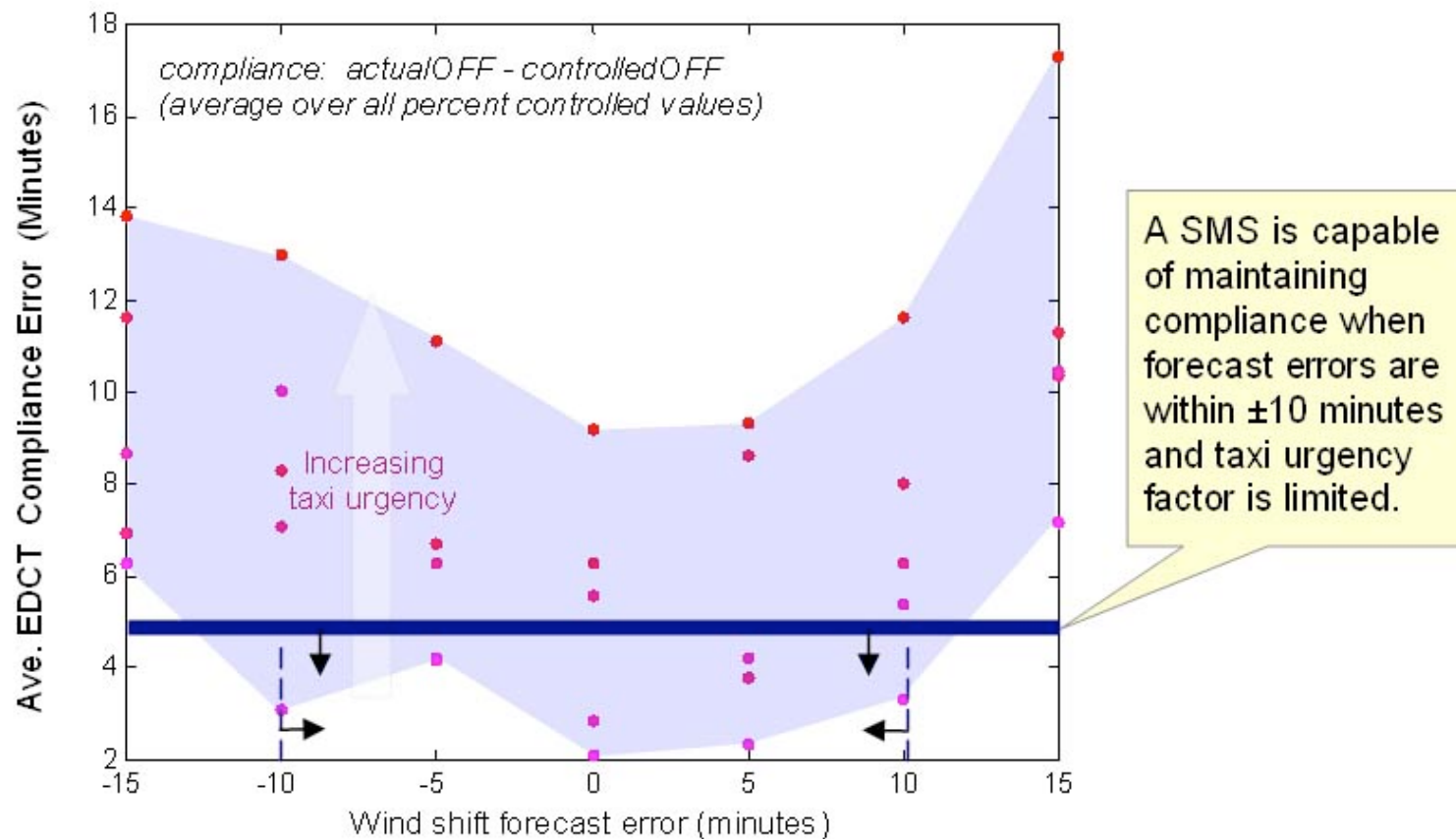
- **Proactive:** Direct aircraft to new runways based on the prediction of when the wind shift occurs
- **Reactive:** Direct aircraft to new runways only after the wind shift occurs; some aircraft will have to re-route to new runways



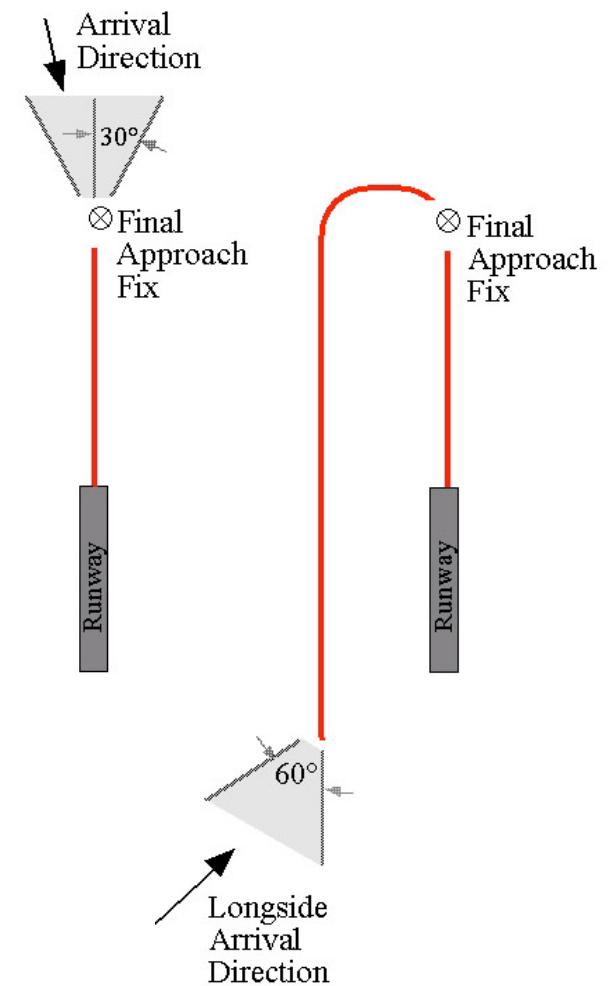
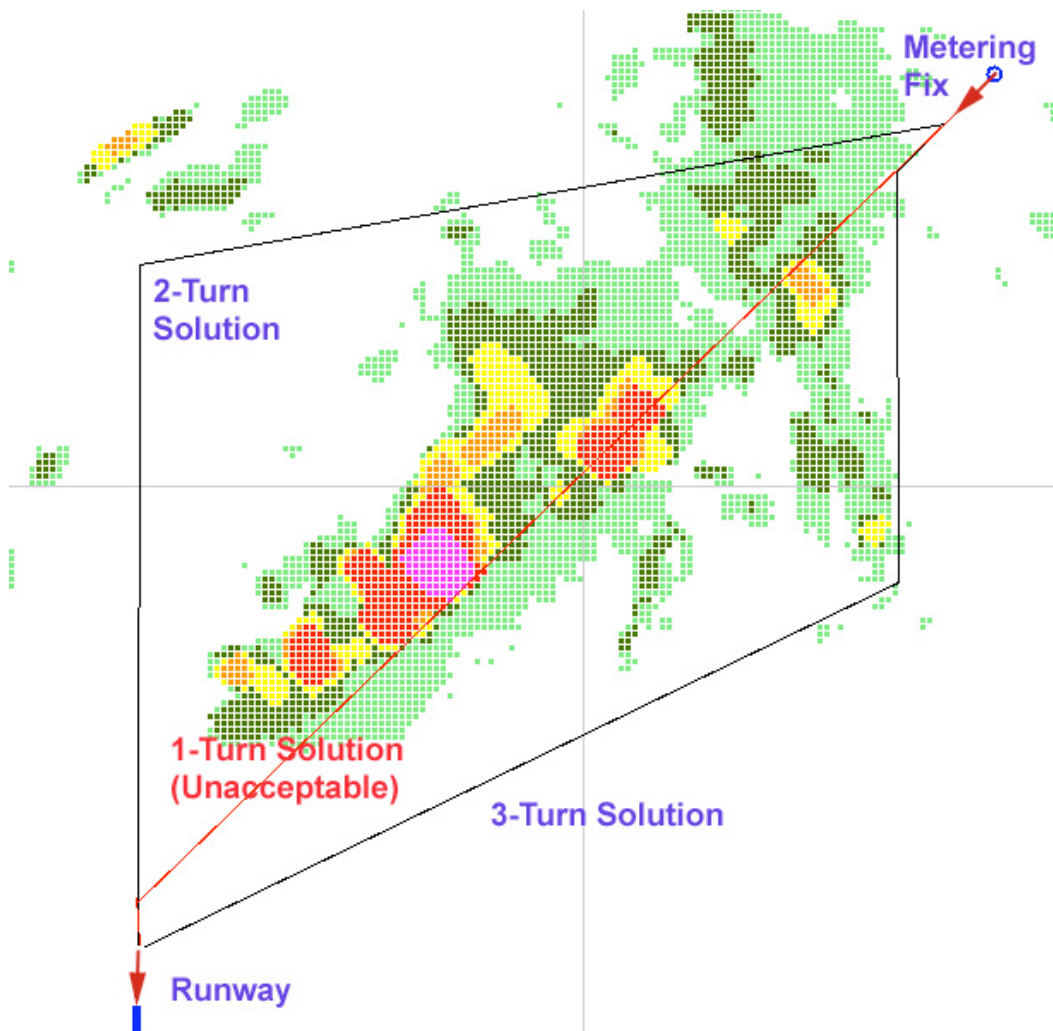
A positive weather time shift denotes winds that occur later than planned.

# SMS EDCT Compliance during Configuration Changes

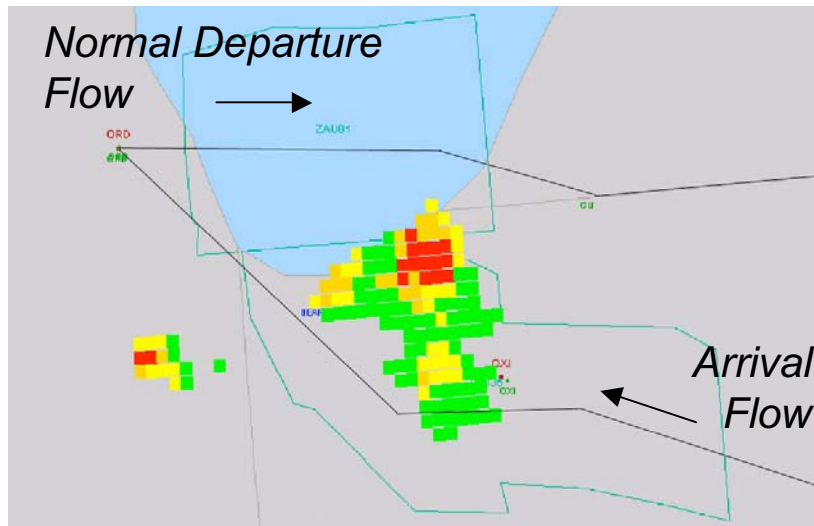
- **Taxi Urgency:** Amount of time the OUT time is ahead of the OFF time (relative to EDCT) ... can EDCT compliance be met by SMS?



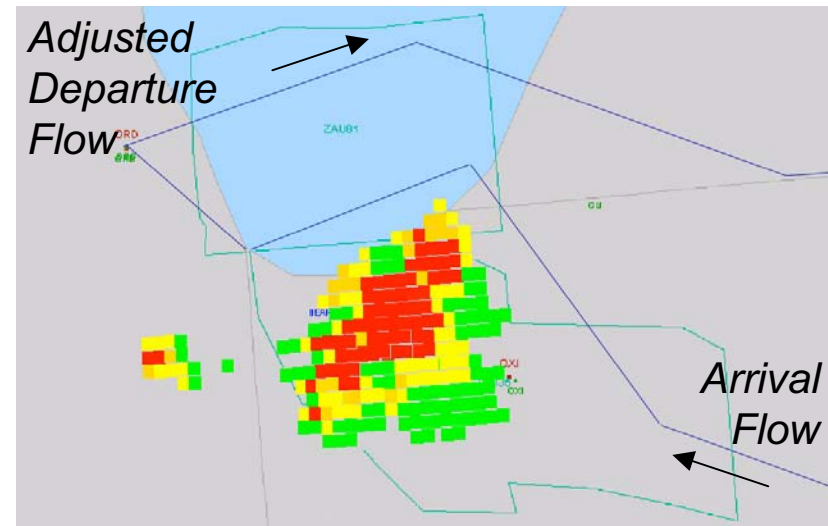
## Core Idea 1.3: Weather Avoidance in the TRACON



## Core Idea 1.4: Weather Avoidance Algorithms for the Transition Airspace

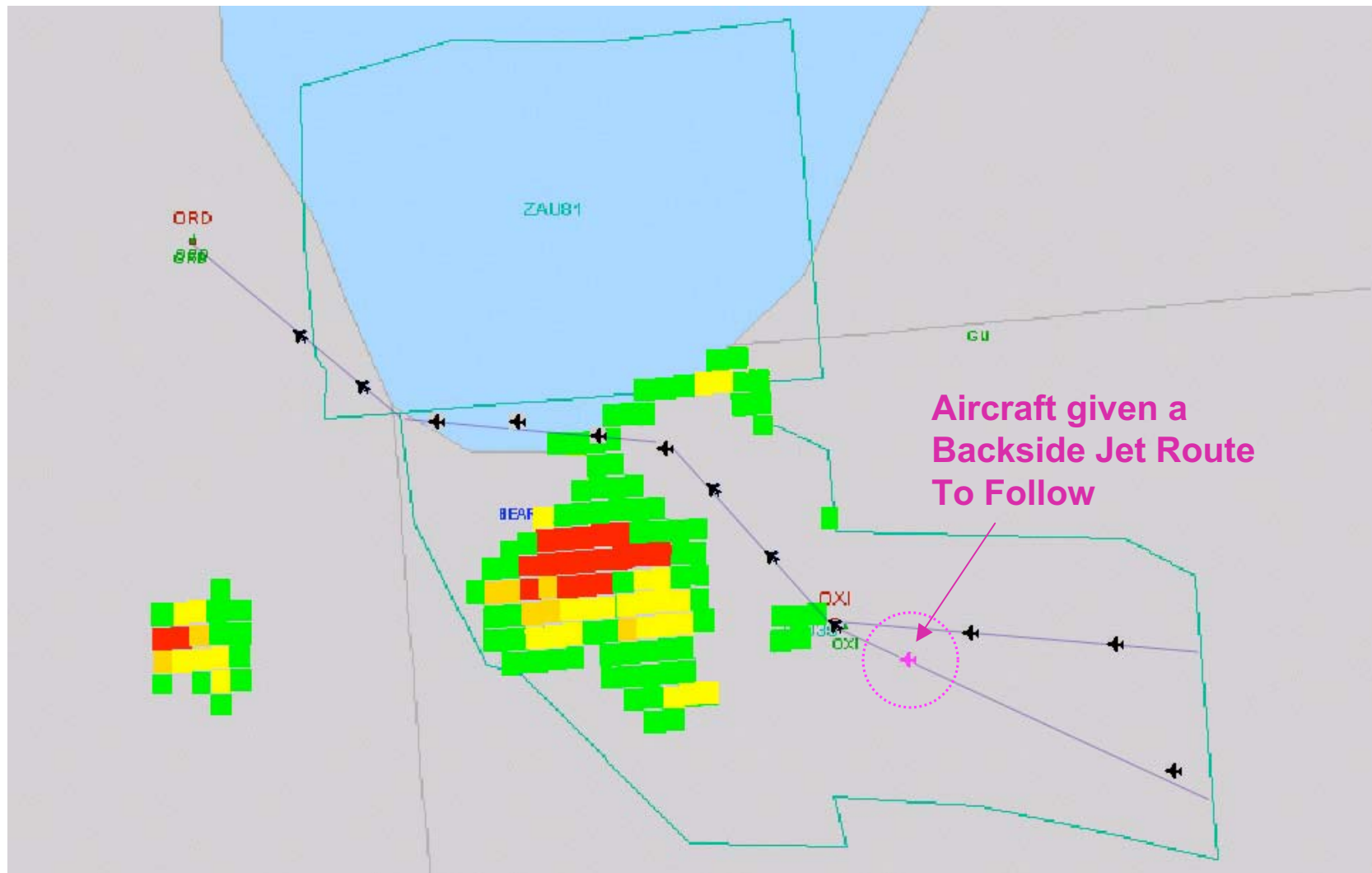


**Departure Flow  
Unaffected by Arrival  
Flow Weather  
Avoidance Route**

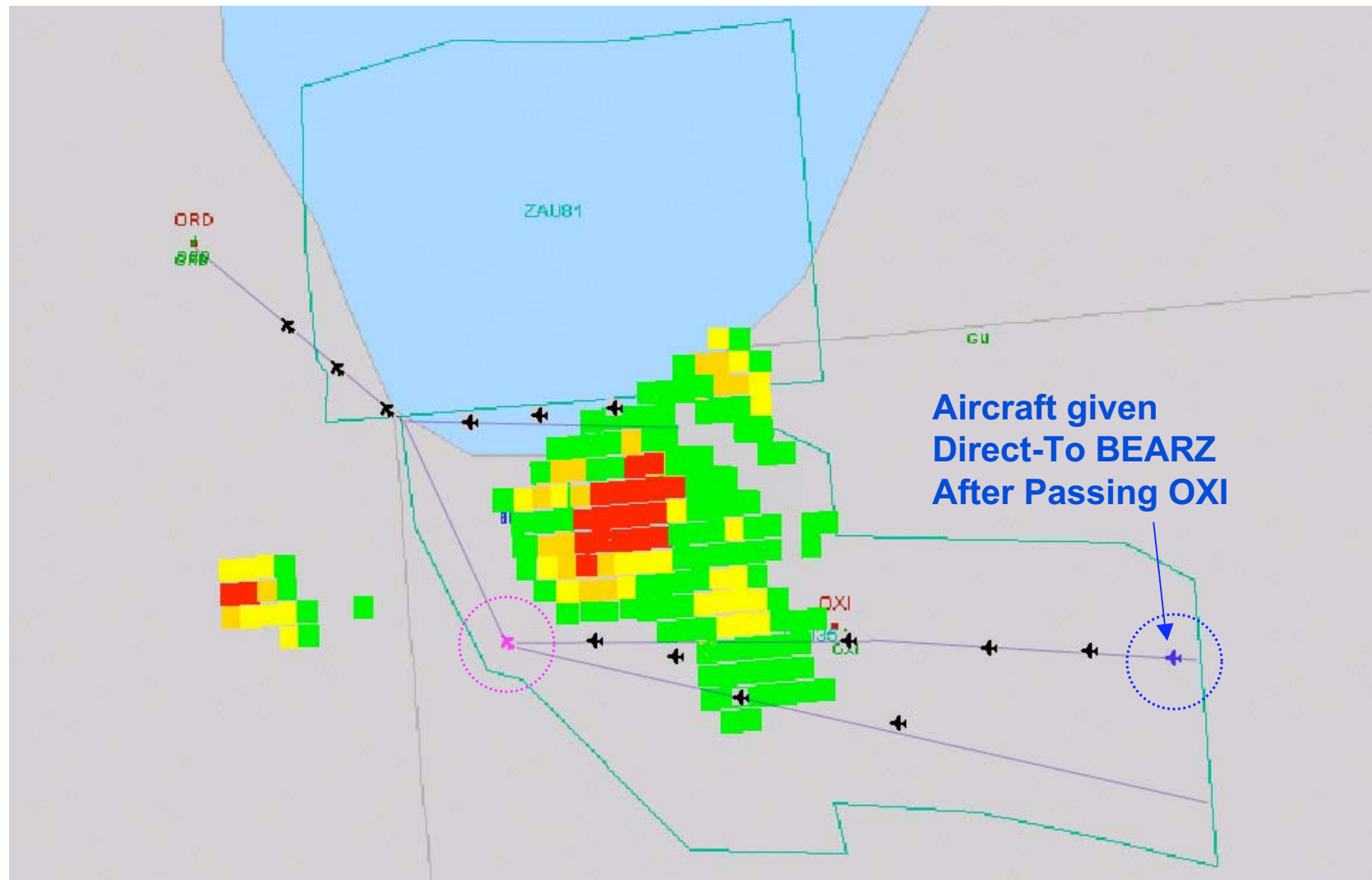


**Departure Flow Re-  
Designed with Arrival  
Flow Weather  
Avoidance Route**

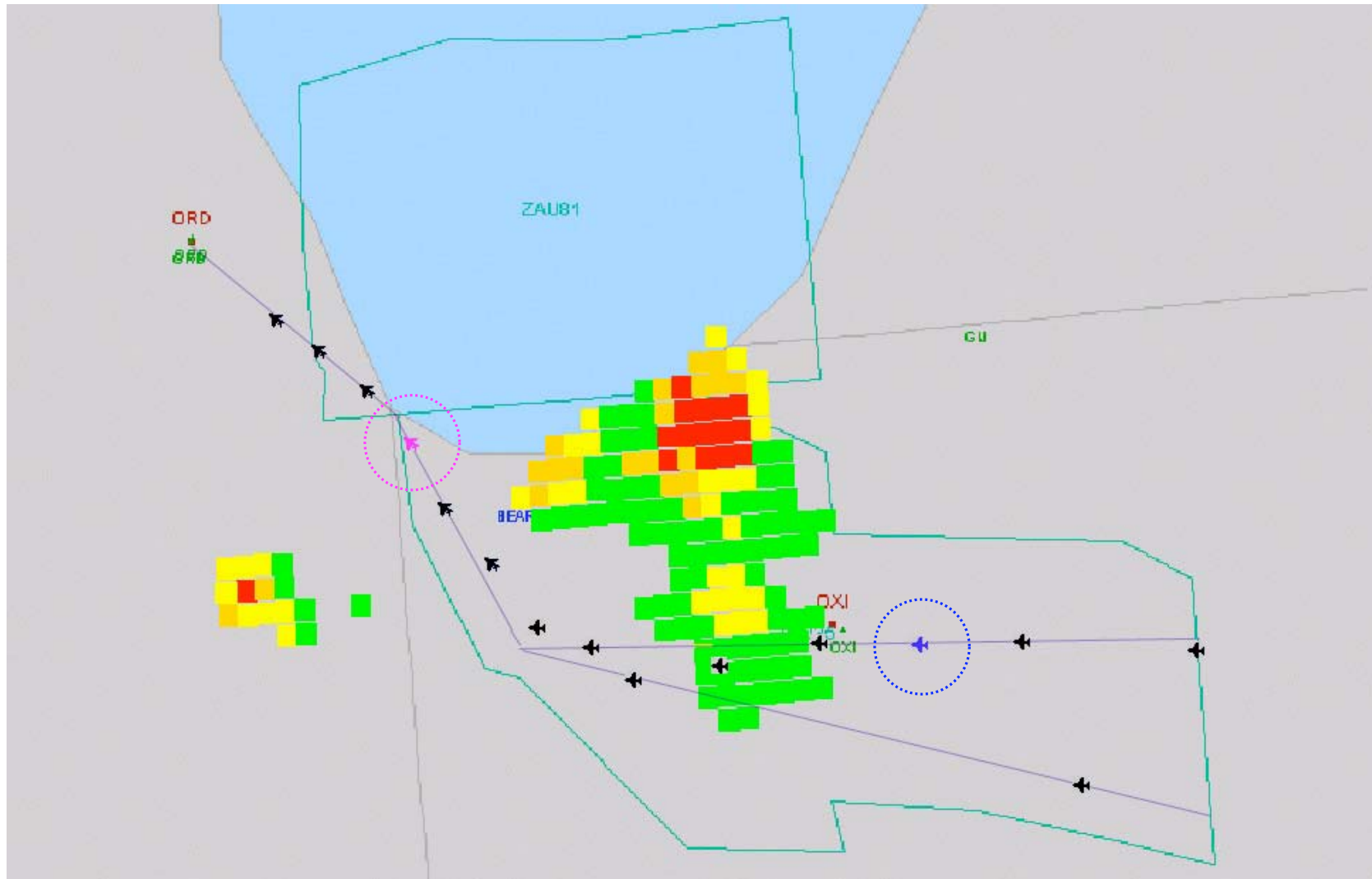
## Example Transition Airspace (1)



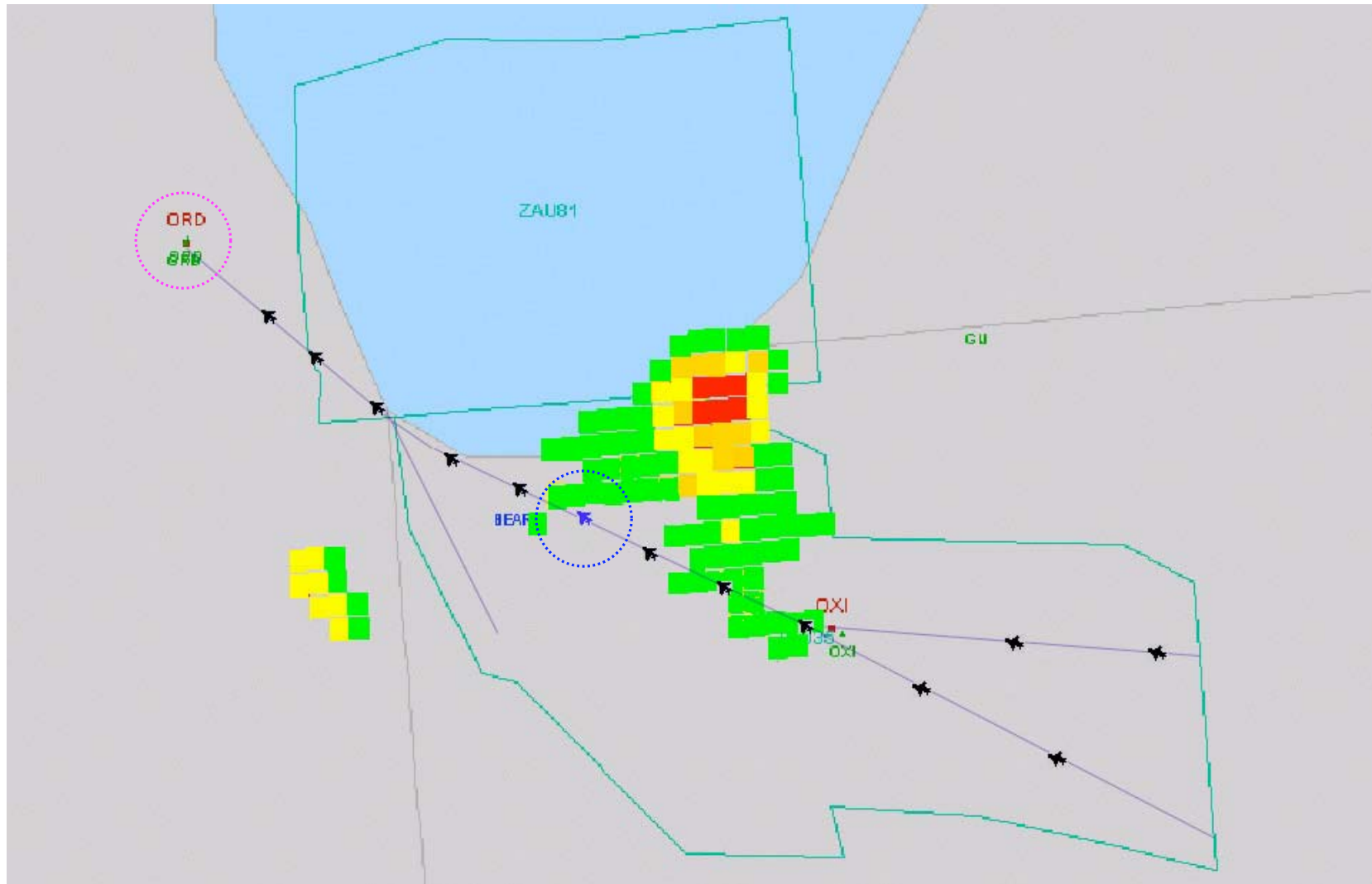
## Example Transition Airspace (2)



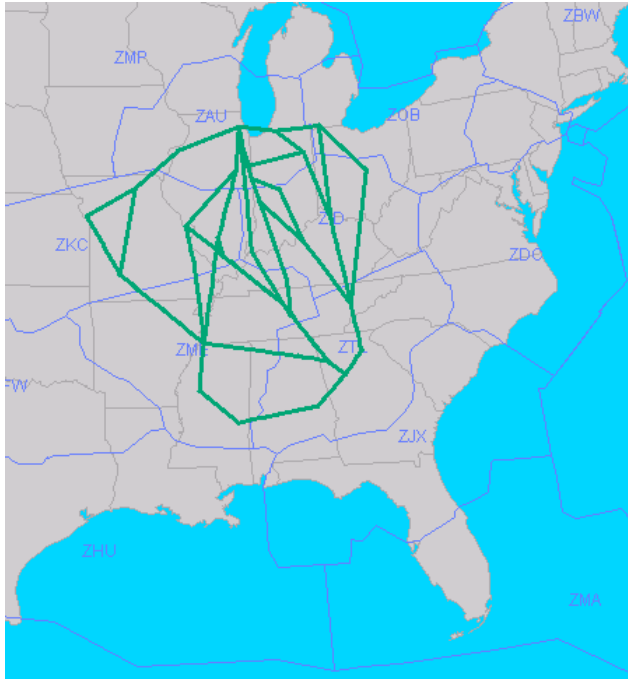
## Example Transition Airspace (3)



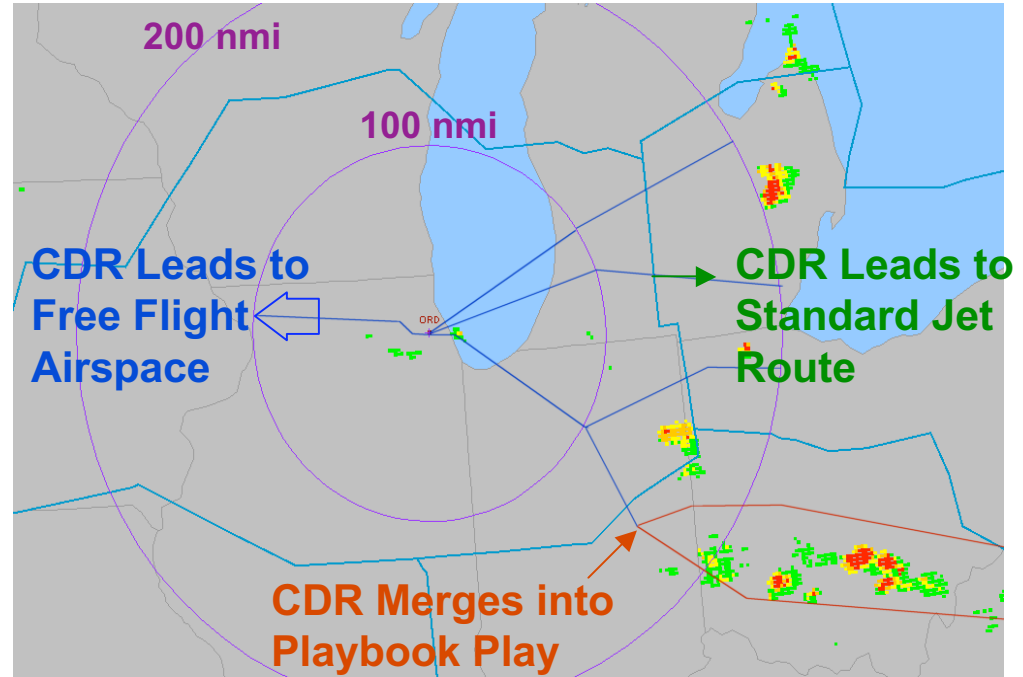
## Example Transition Airspace (4)



## Core Idea 1.4: Weather Avoidance Algorithms for the Transition Airspace

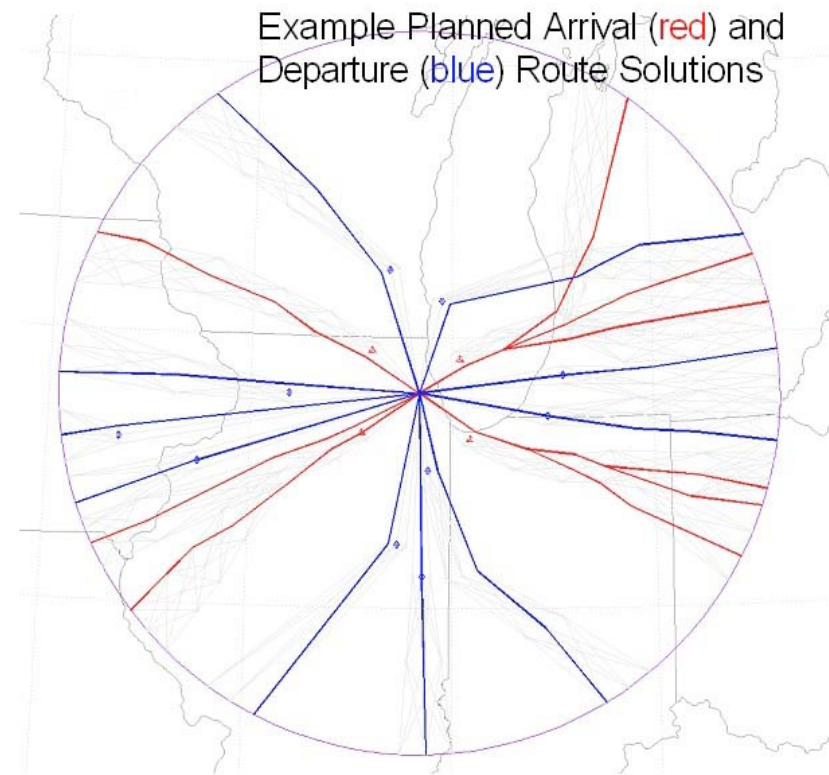
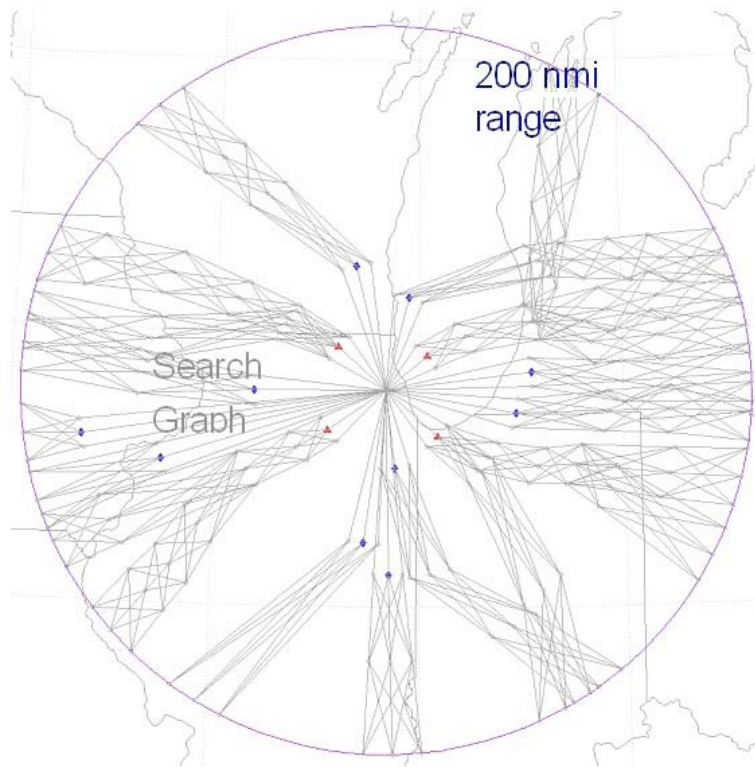


**Current CDRs Extend from Departure Airport to Arrival Airport**



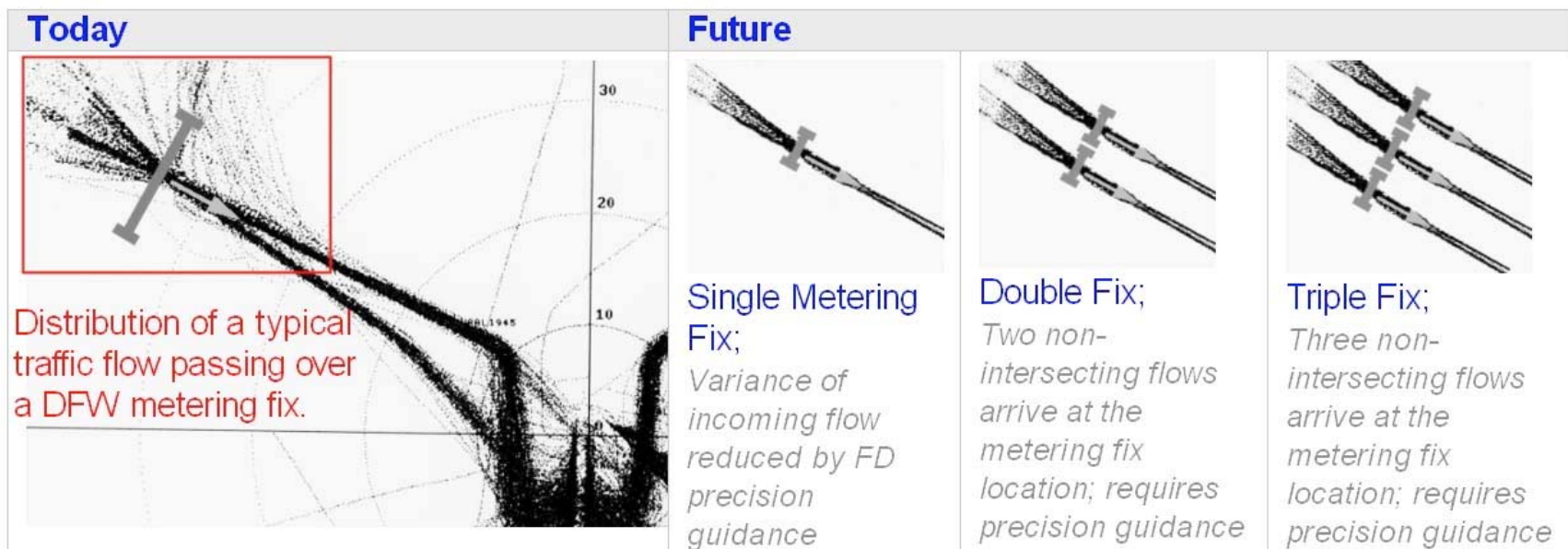
**Range-Based CDRs Extend out a Fixed Range and Merge with Free Flight Airspace, Standard Jet Routes, or Playbook Plays**

# Method 1: Alternate Waypoints via Variable SIDs & STARs

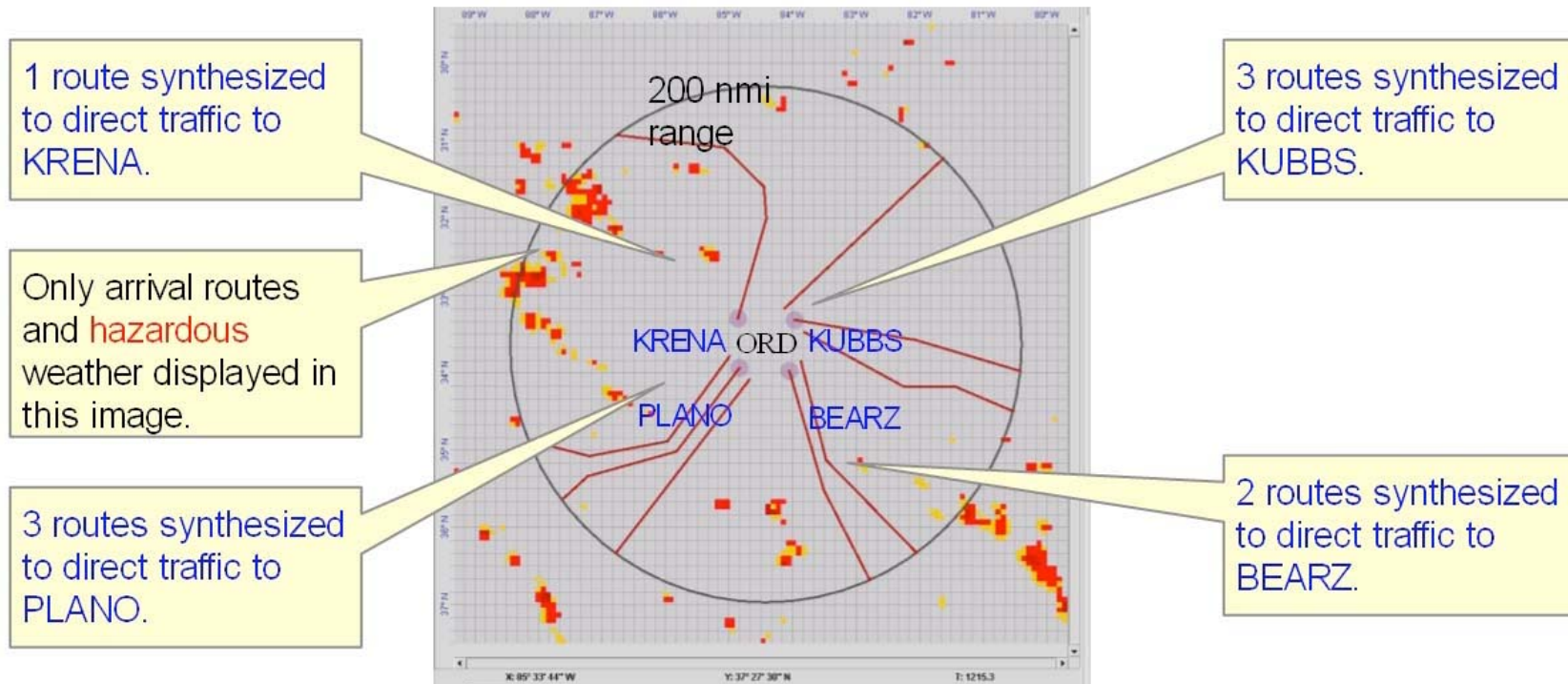


# Concept: Single, Double, Triple Metering Fixes

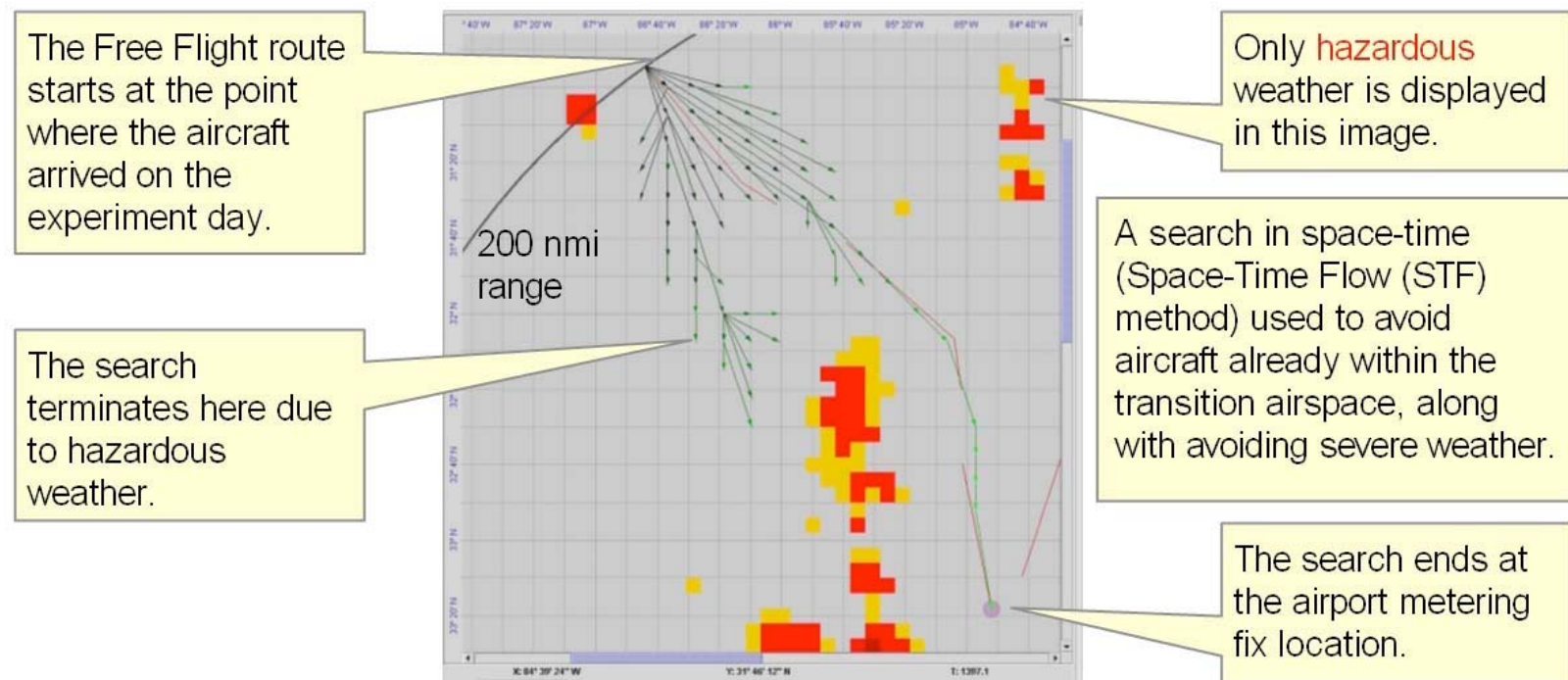
- **2x Throughput:** Can we create 2 Metering Fixes that are closely spaced together to meter 2x the Fix Throughput to an airport?
- **3x Throughput:** Can we create 3 Metering Fixes?



## Method 2: Non-Intersecting Parallel Flows to Single, Double, or Triple Metering Fixes

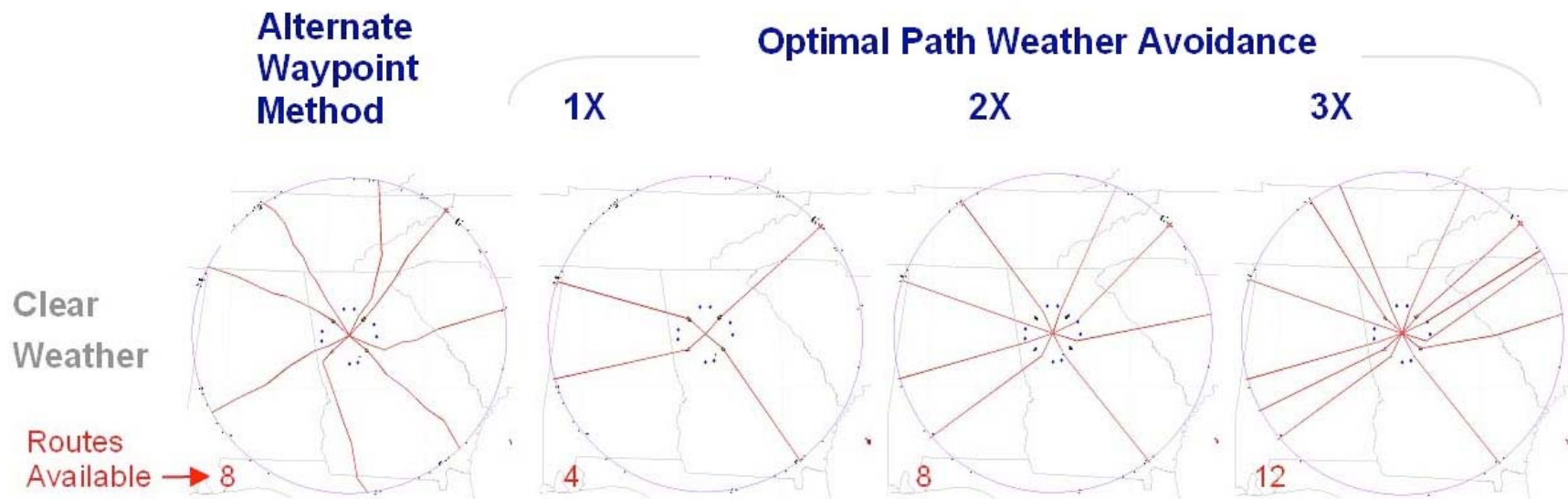


## Method 3: Free Flight to Single, Double, or Triple Fixes

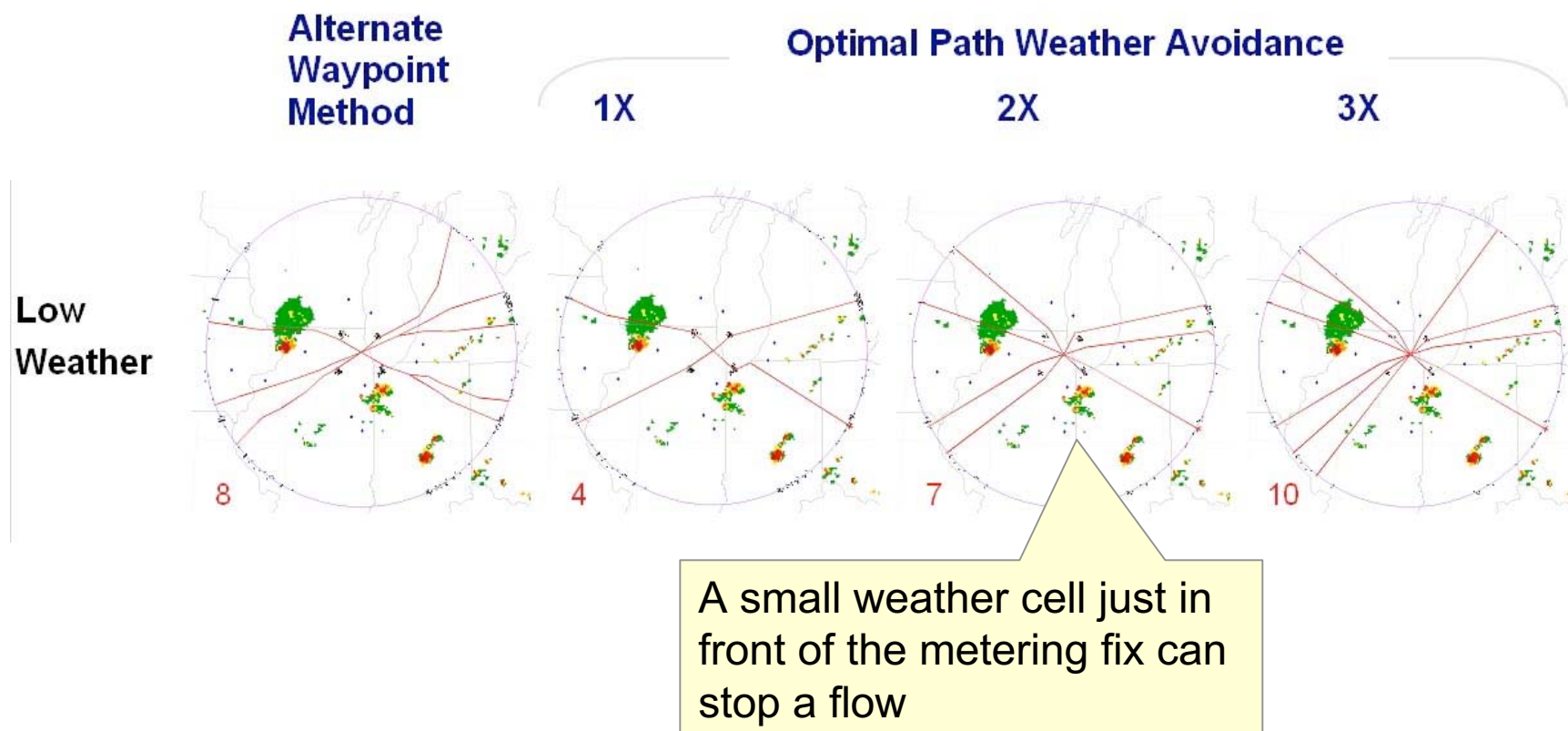


# Comparison: Variable STARs vs Parallel Routes

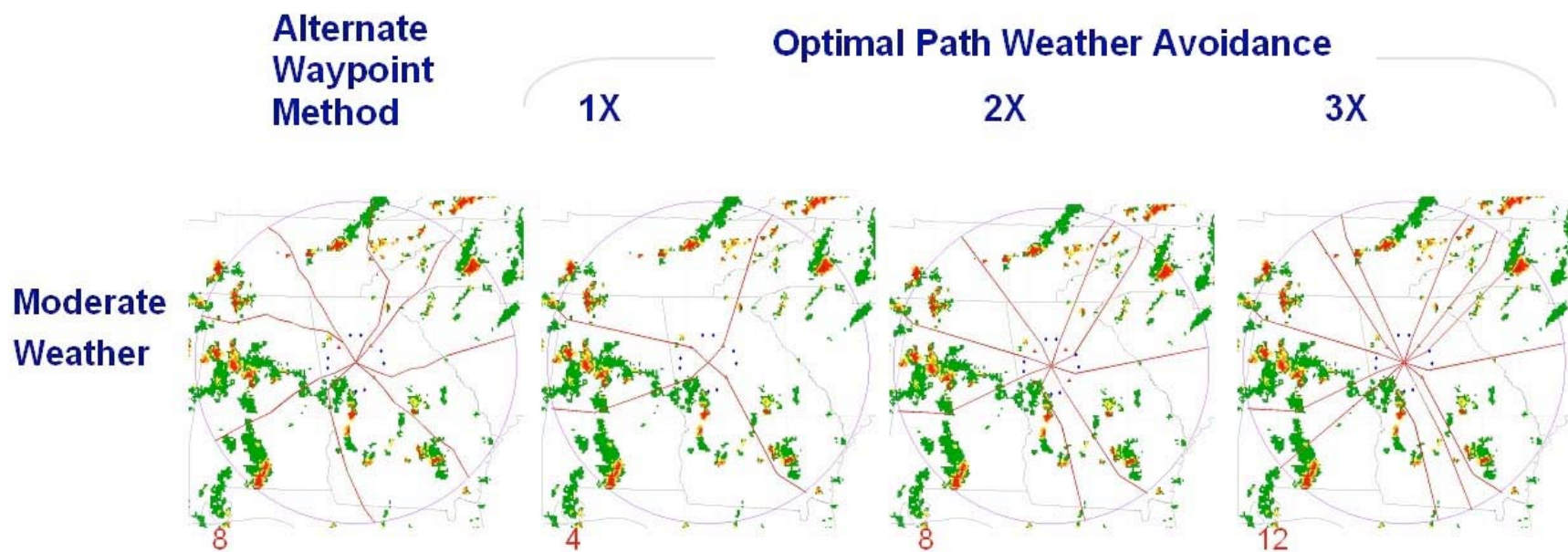
- Note: Only Arrival Routes are Shown



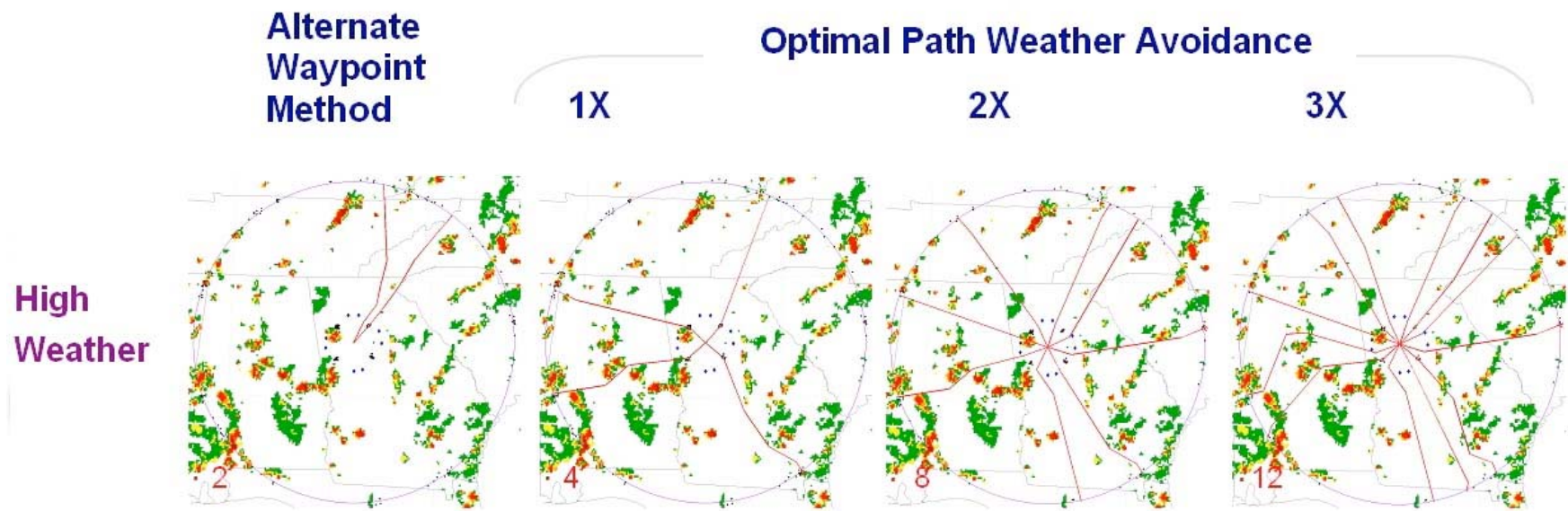
# Comparison:



# Comparison:

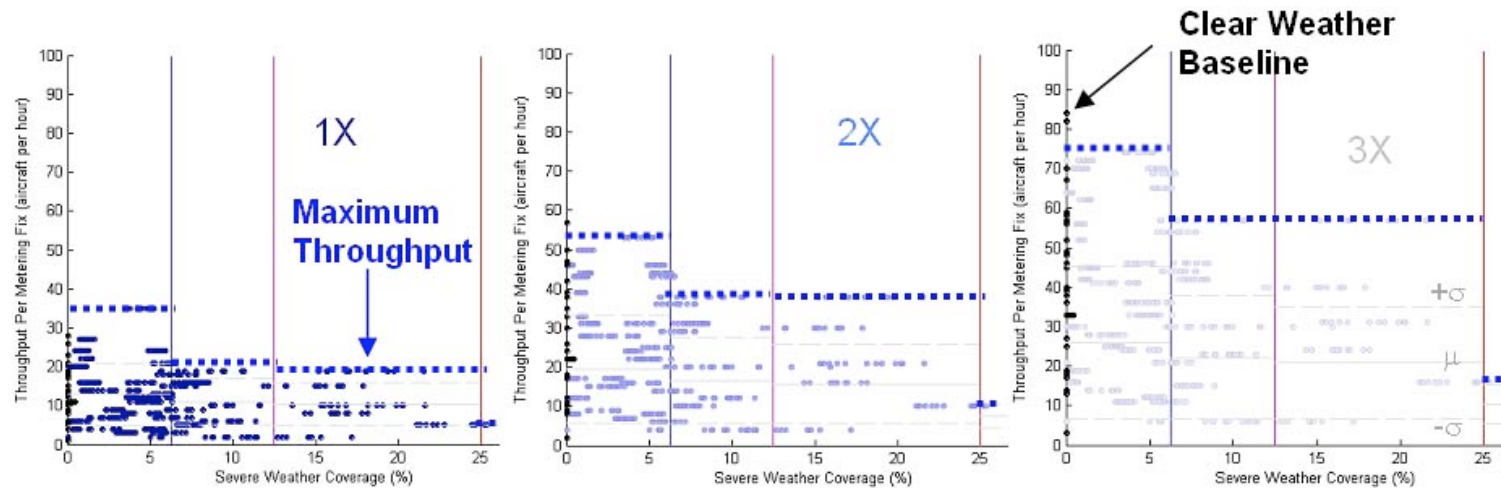


# Comparison:

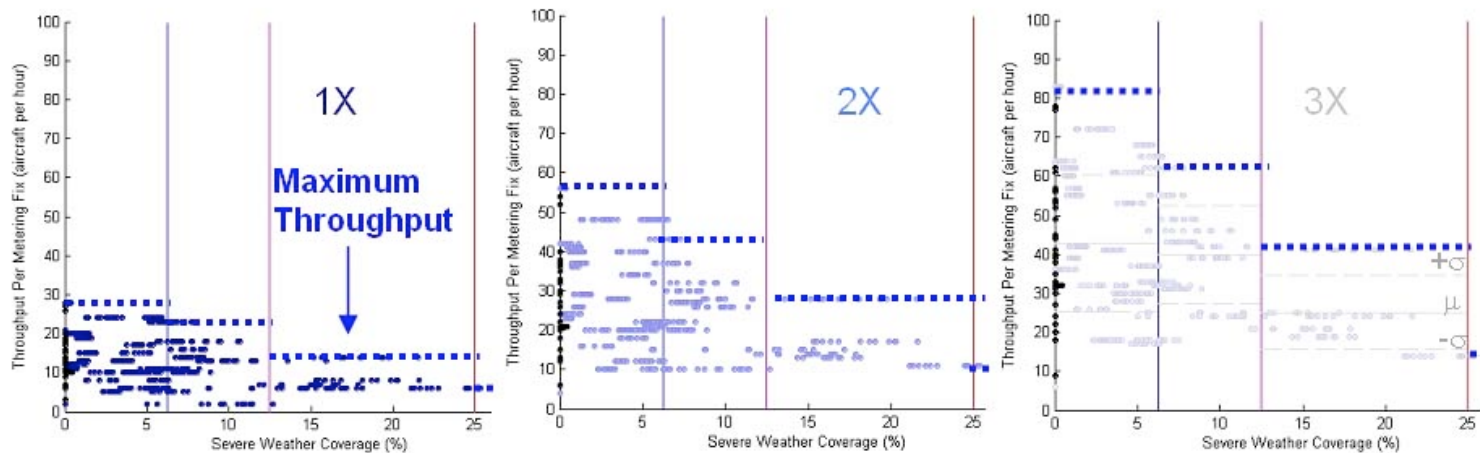


# Comparison: Parallel Jet Routes vs Free Flight to Single, Double, or Triple Fixes

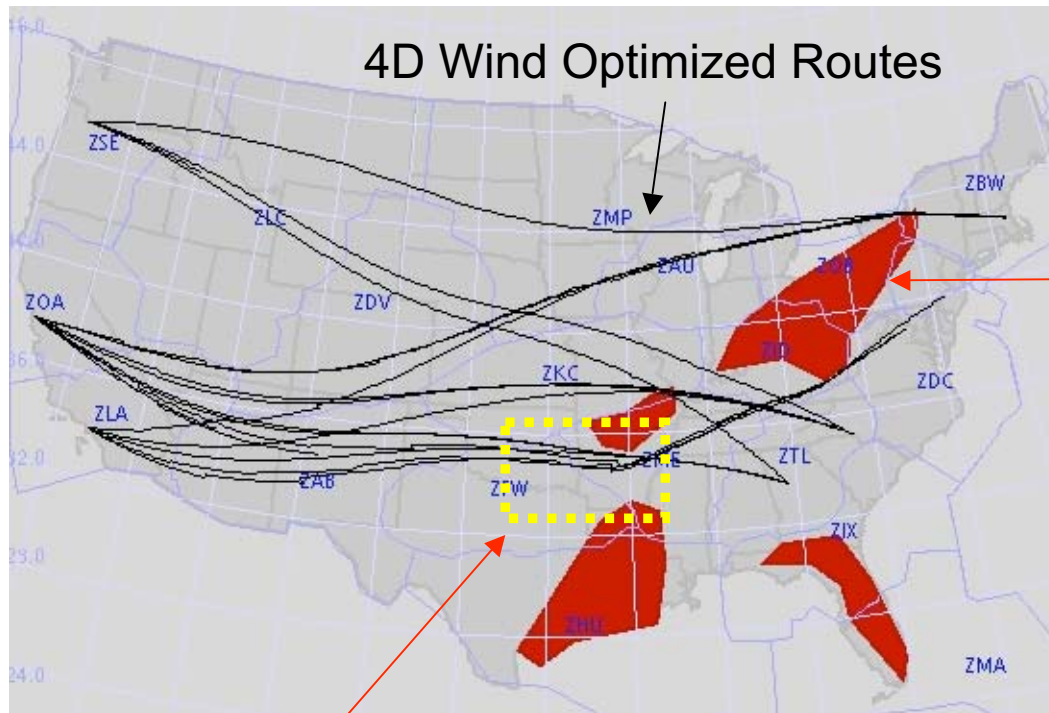
## Parallel Routes



## Free Flight

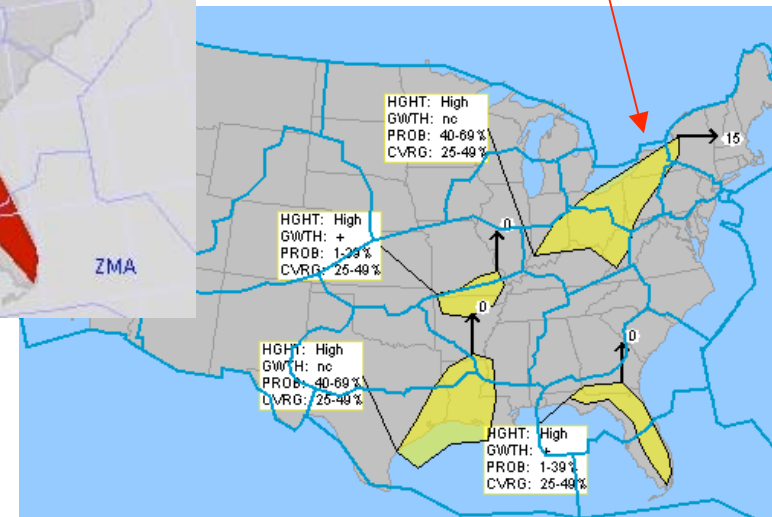


## Core Idea 1.5: Wind-Optimal Free Flight Routes



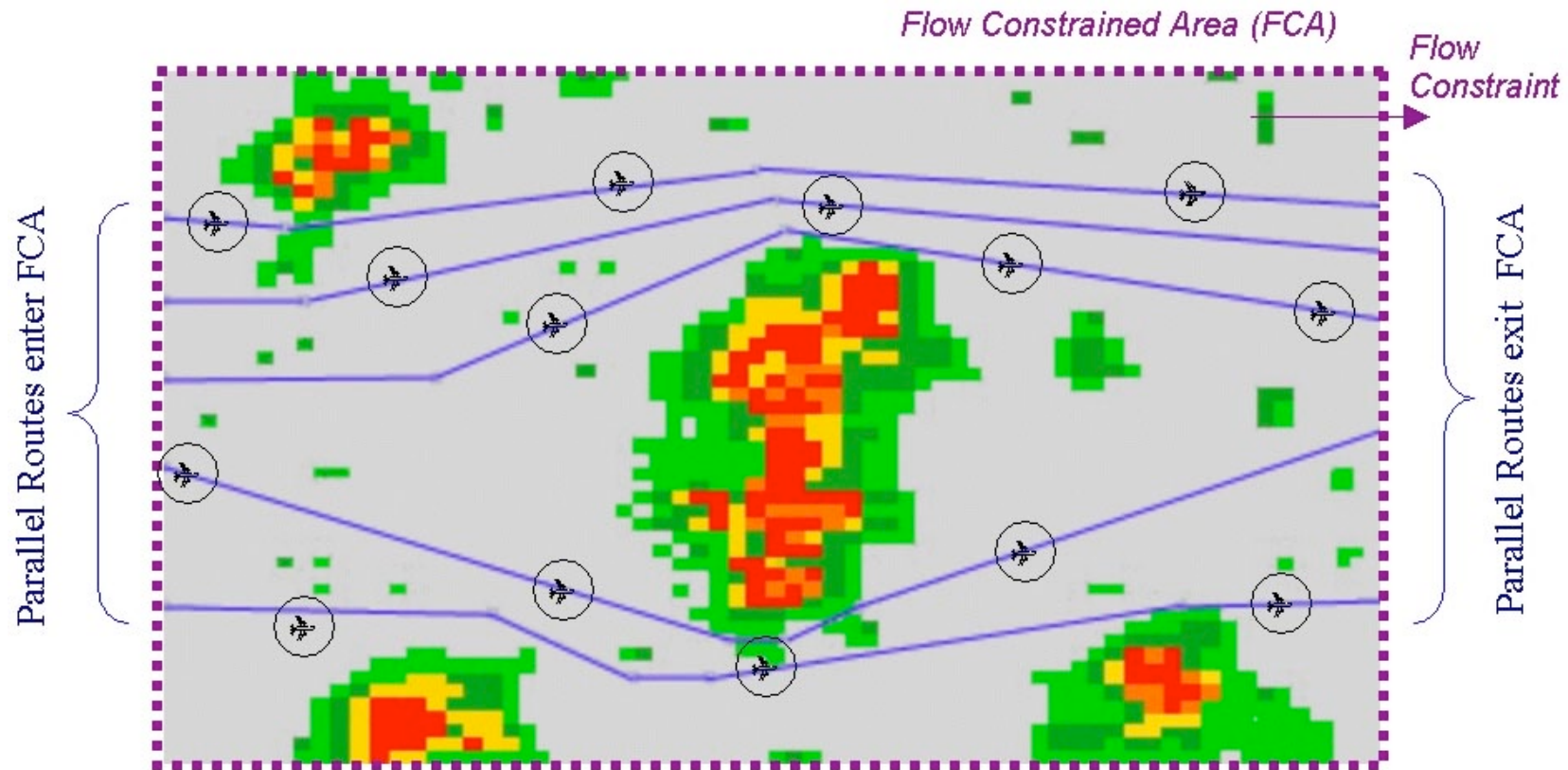
Future (4D)  
Weather  
Constraint or  
Today's CCFP

Flow Constrained Area (FCA)



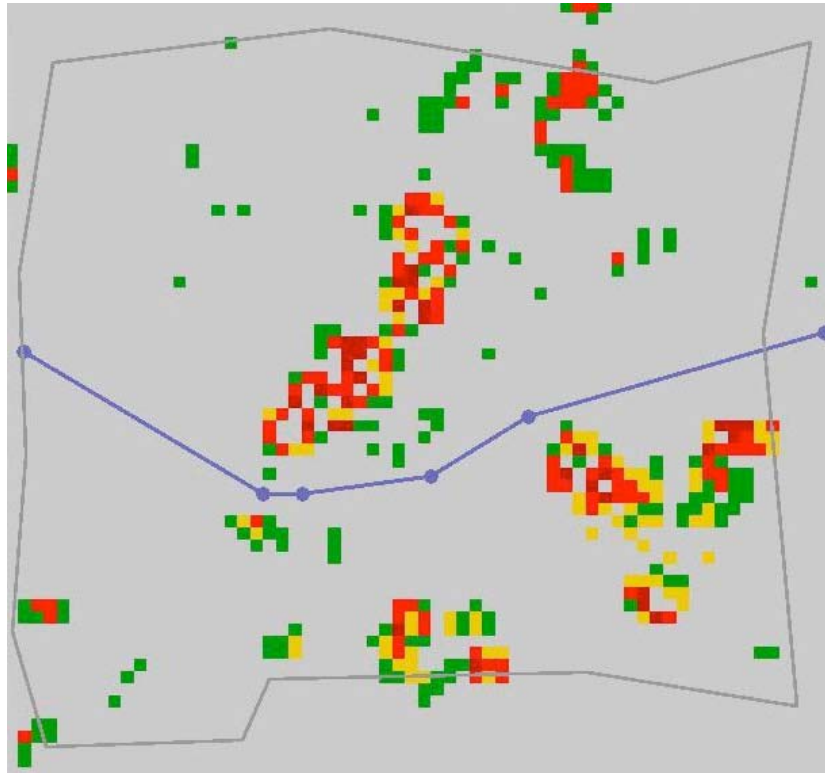
Method of Jardin (NASA) modified to avoid large Weather Constraints

## Core Idea 1.5: Weather Avoidance Algorithms for En Route Aircraft



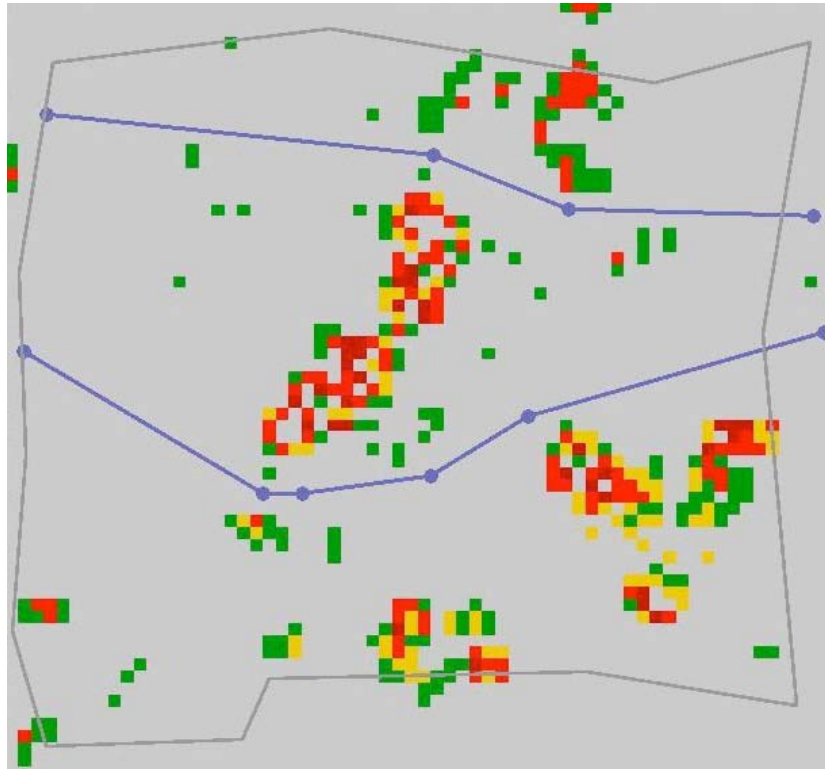
**Parallel Routes Dynamically Defined Around Weather Constraints**

# Weather Avoidance Algorithms for En Route Aircraft



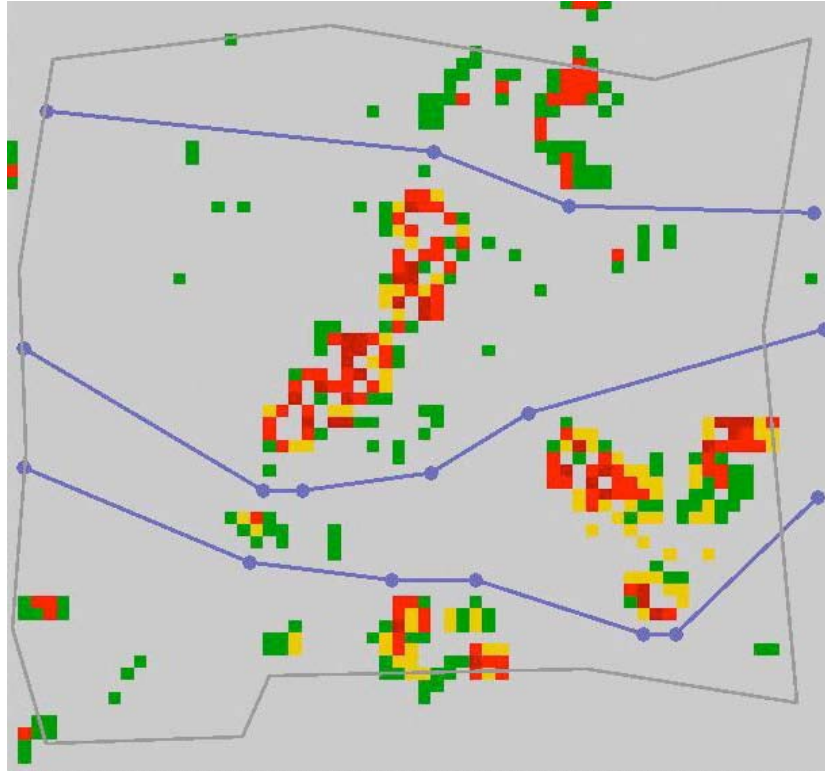
1 Flow

# Weather Avoidance Algorithms for En Route Aircraft



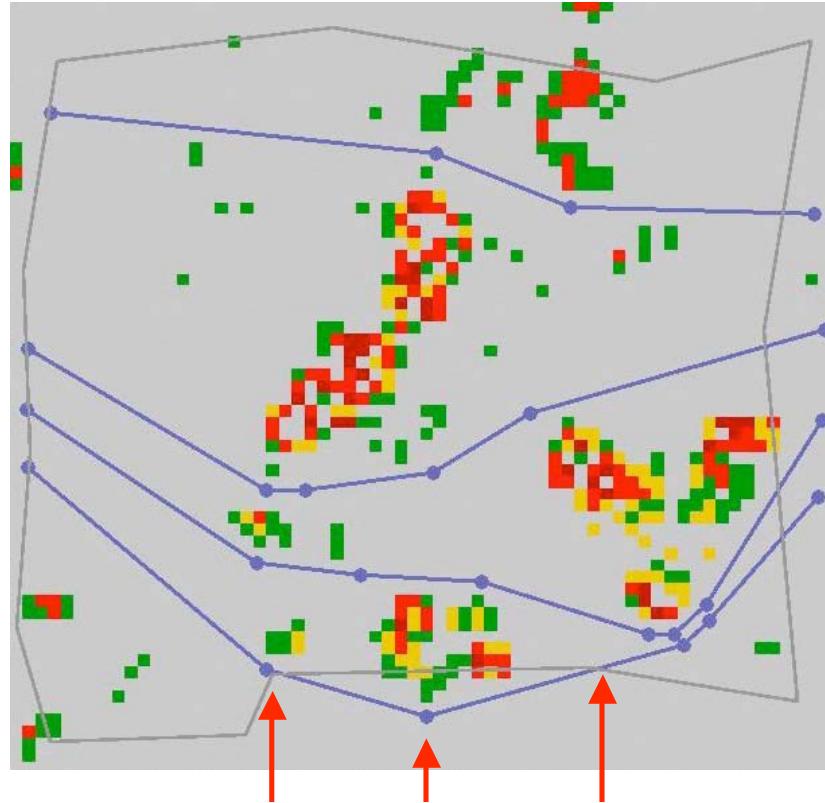
2 Flows

# Weather Avoidance Algorithms for En Route Aircraft



3 Flows

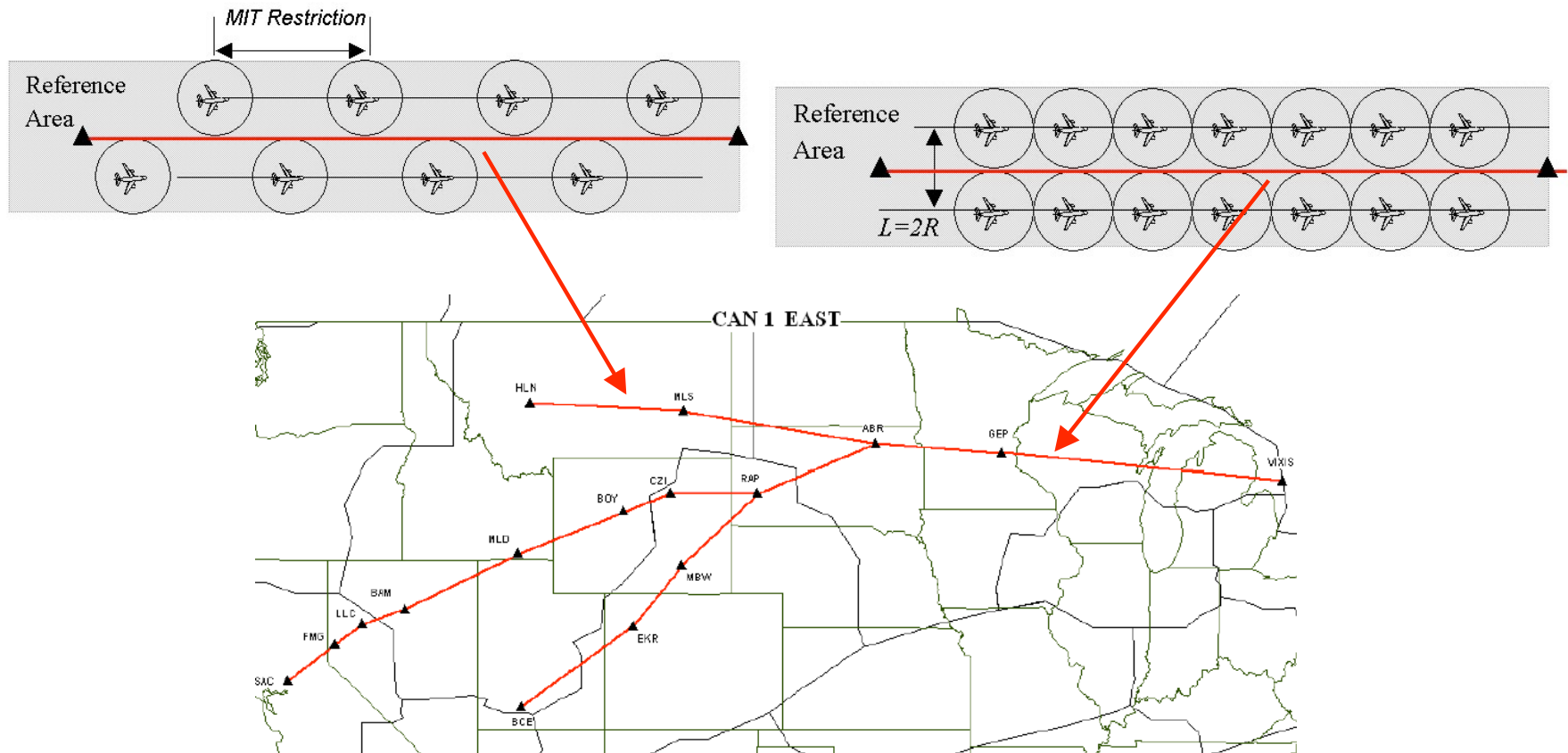
# Weather Avoidance Algorithms for En Route Aircraft



**Violation of Boundary Constraint**

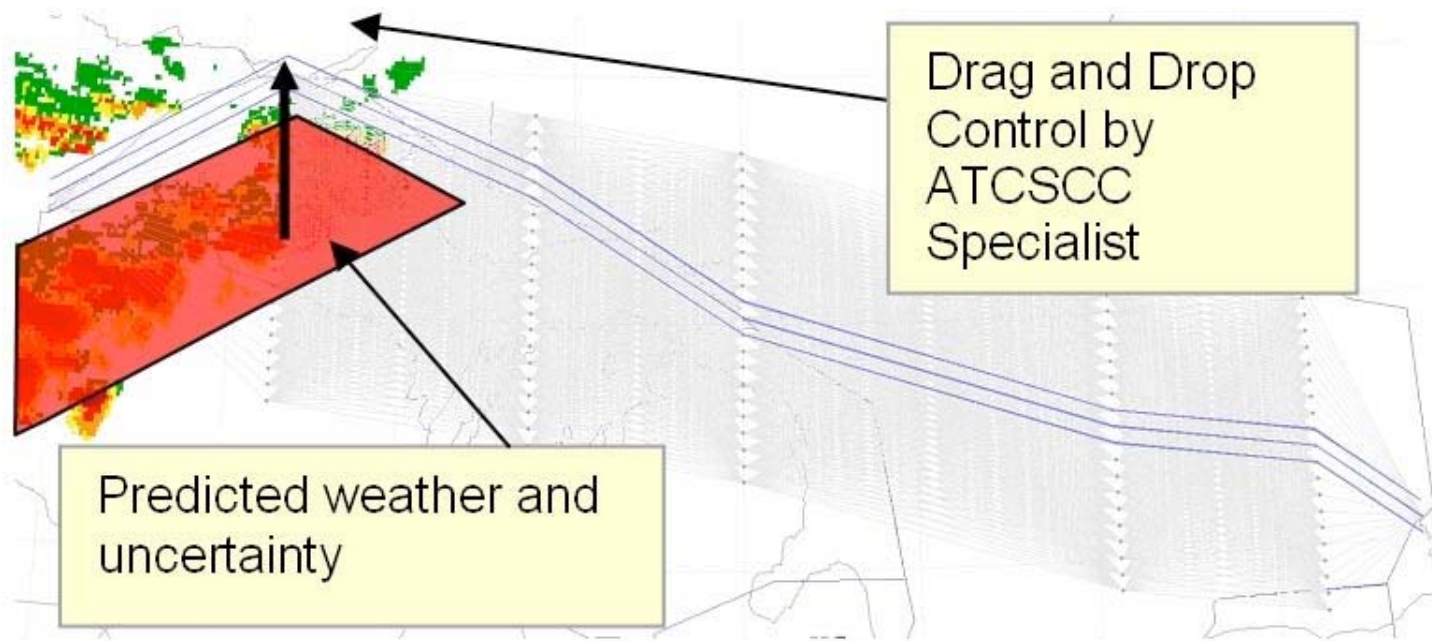
**4 Flows**

## Core Idea 1.6: Coordination of Large Scale TFM Plans



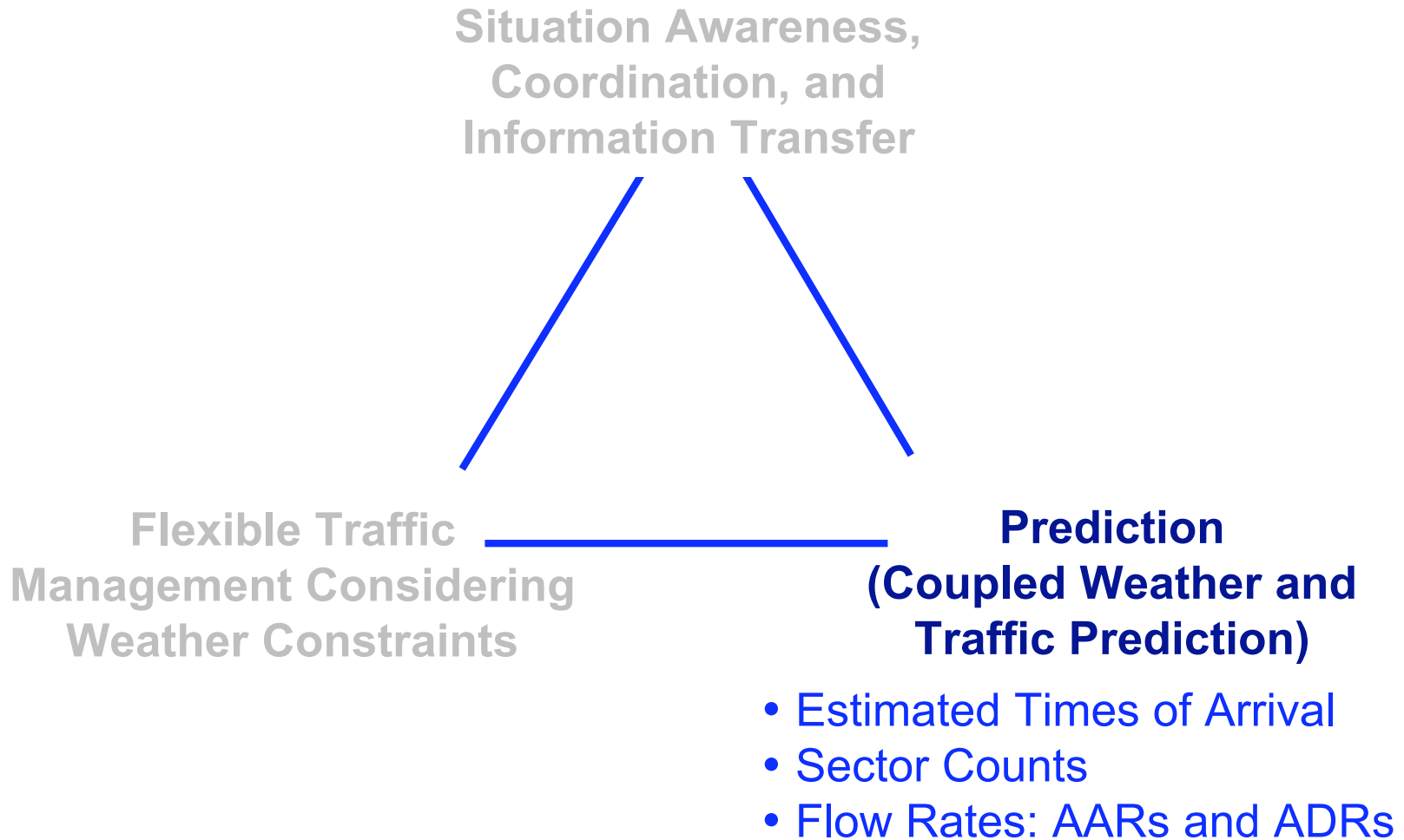
### Parallel Routes Applied to Playbook Plays

## Core Idea 1.6: Coordination of Large Scale TFM Plans

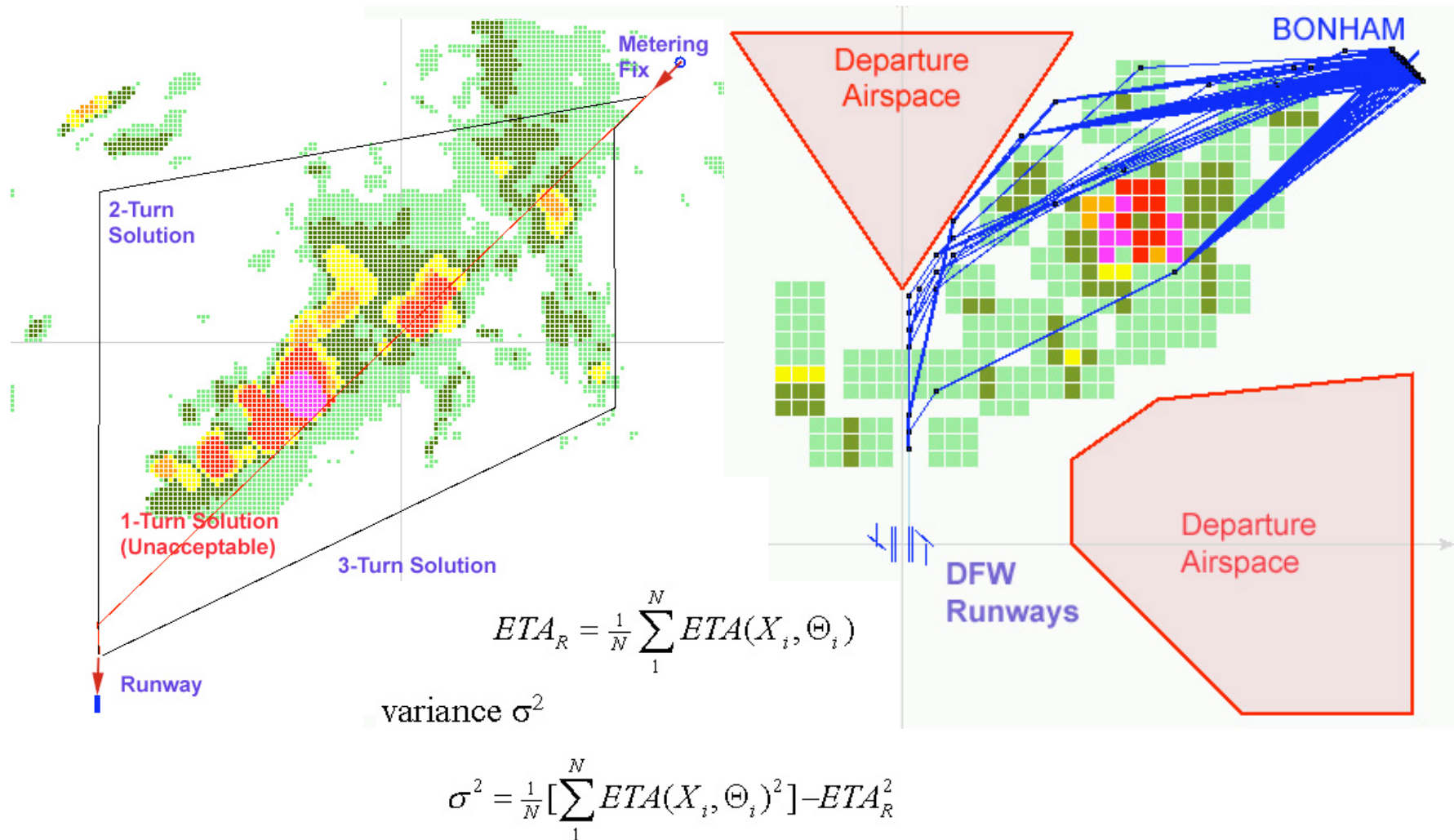


### Parallel Routes Applied to Playbook Plays

## Core Idea 2:

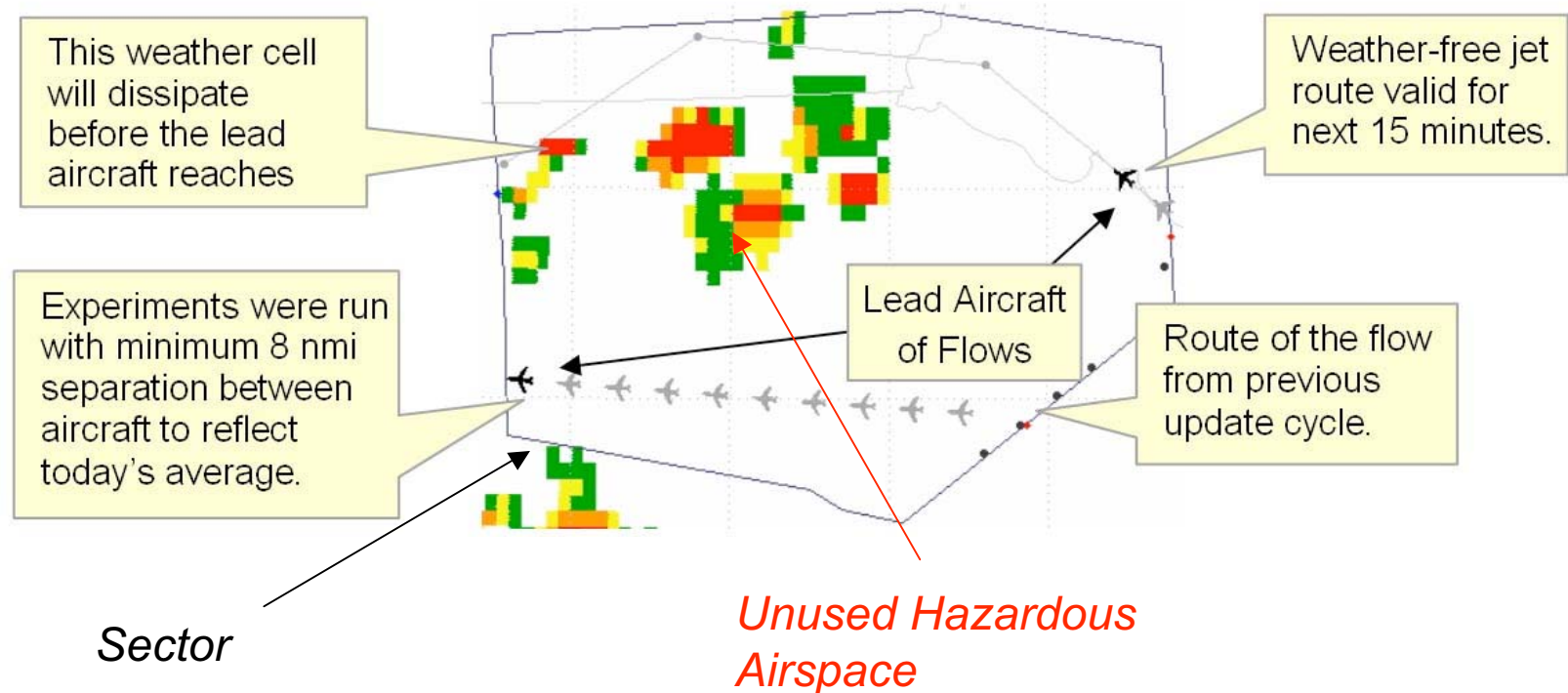


## Core Idea 2.1: Incorporate Weather Predictions into ETAs



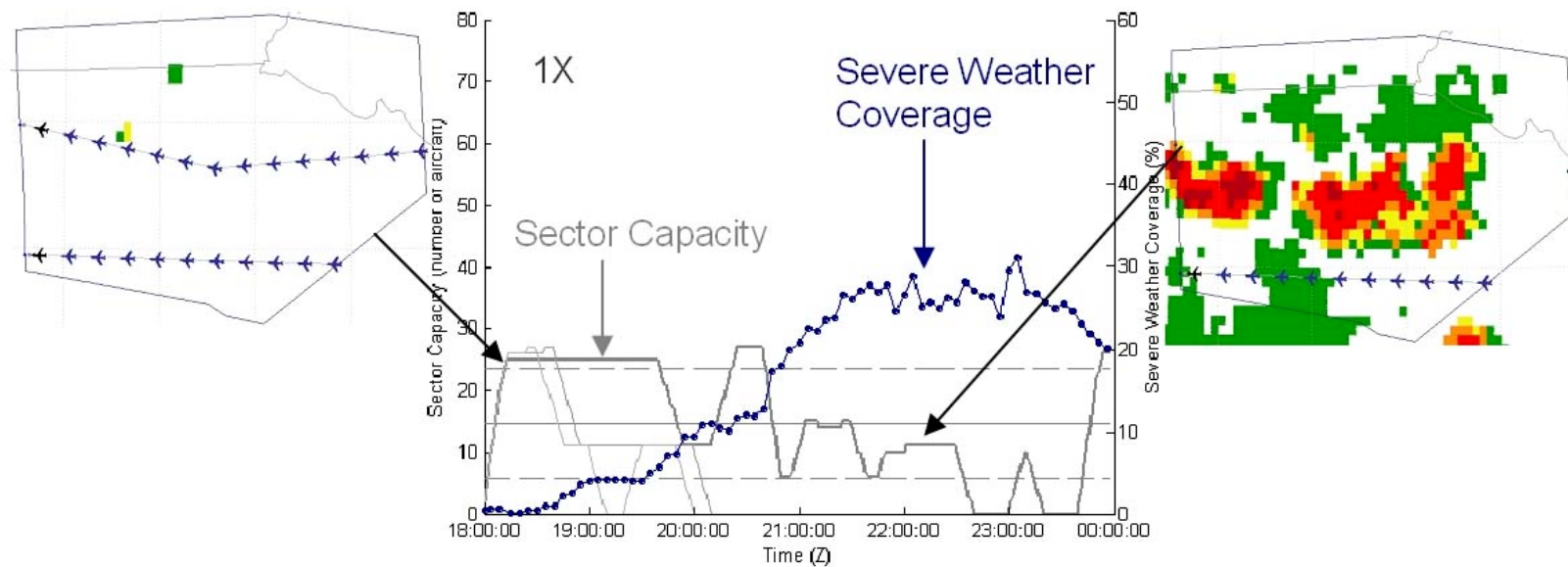
## Core Idea 2.2: Sector Demand Predictions and Weather

- Estimate Sector Loads based on Trajectory Predictions that include Weather Constraints
- Dynamically adjust the Sector Load Capacity to account for the amount of Unused Hazardous Airspace Present in the Sector



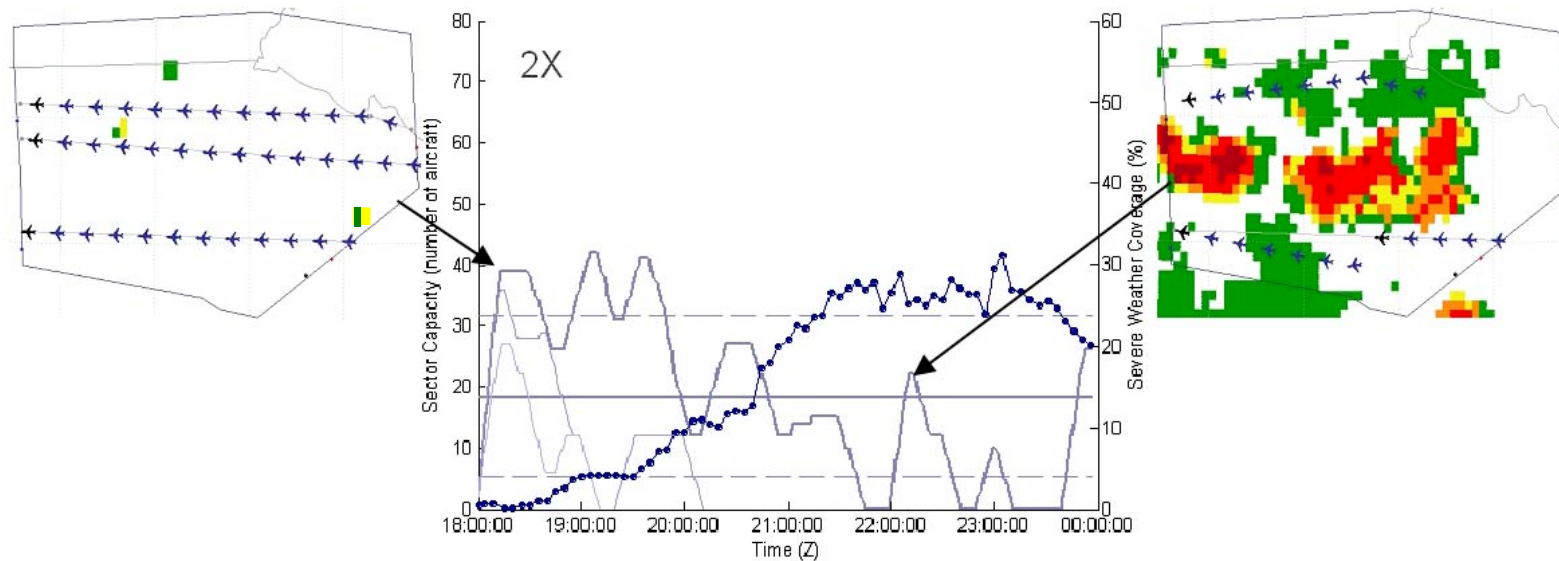
## Core Idea 2.2: Self Assessment Result

- **Constraint: 1x Capacity Limit**



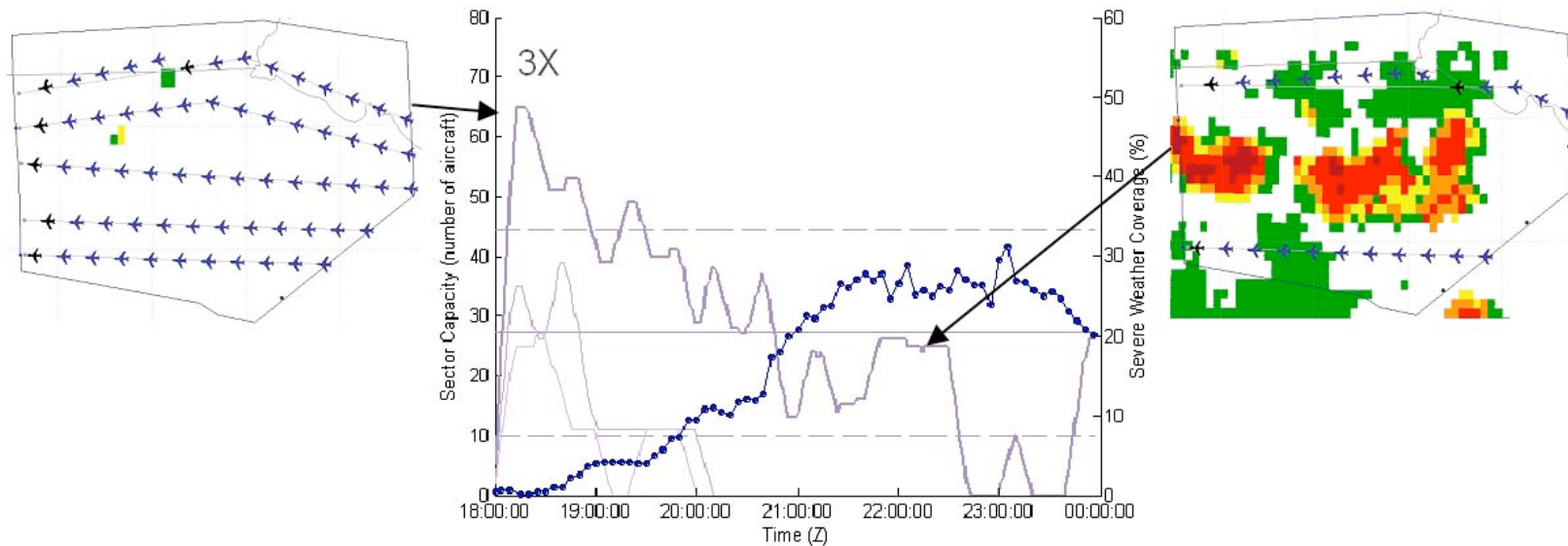
## Core Idea 2.2: Self Assessment Result

- **Constraint: 2x Capacity Limit**

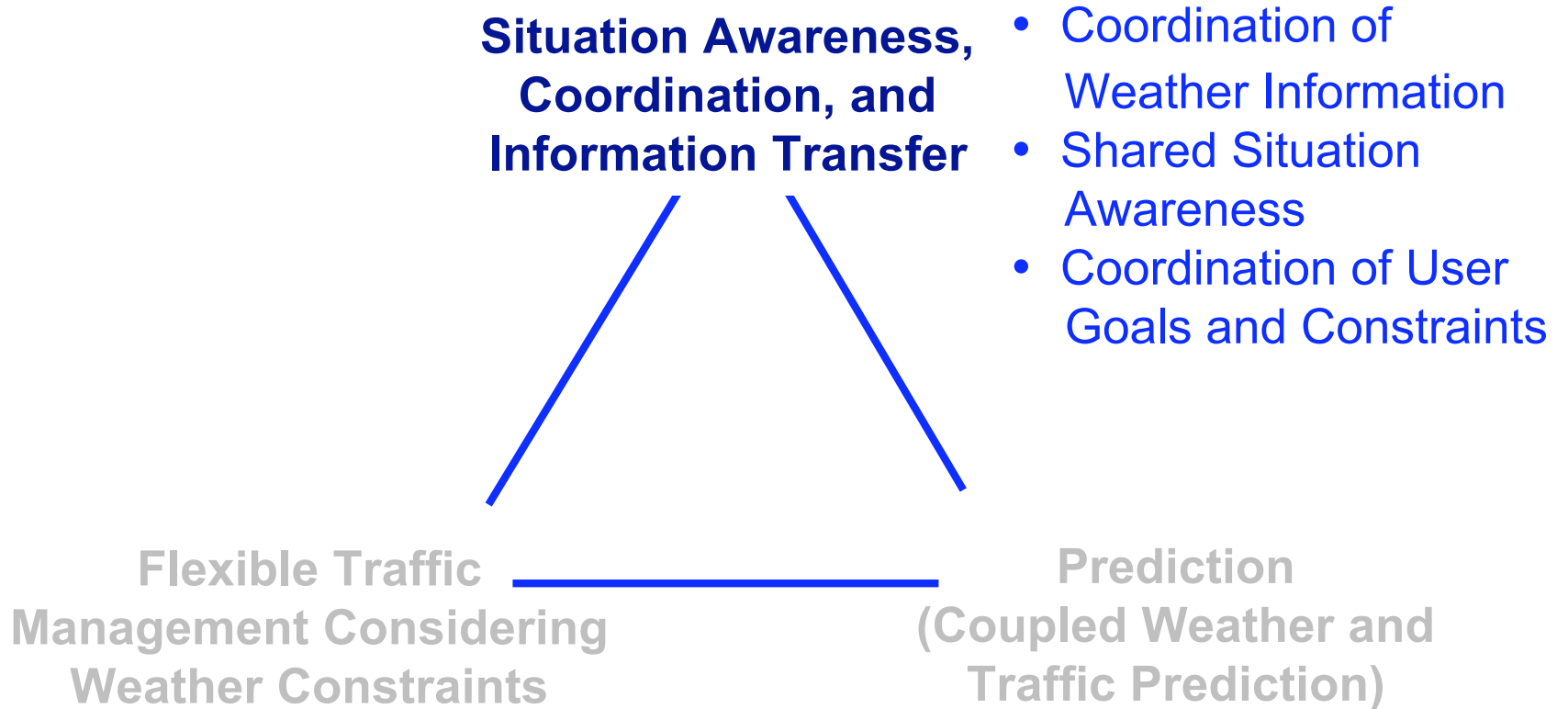


## Core Idea 2.2: Self Assessment Result

- **Constraint: 3x Capacity Limit**

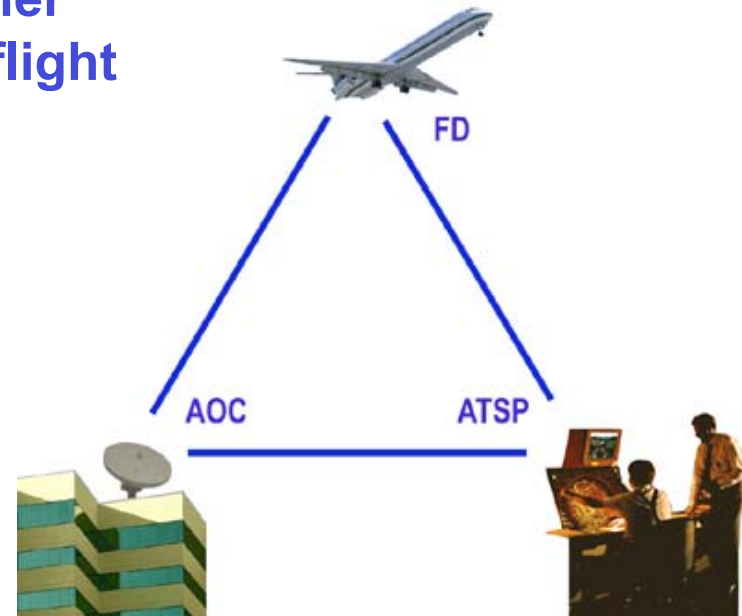


## Core Idea 3:



## Core Idea 3.1: Coordination of Weather Information

- Weather information (actual weather and its effects) from a variety of sources needs to be collected, compared, integrated, fused, coordinated, and distributed.
- Information on the surface needs to be combined with information in the air to provide NAS-wide mosaic of weather conditions affecting all phases of flight
- Sources include:
  - MDCRS data
  - PIREPs
  - Radar Data
  - Satellite Data
  - Surface Conditions



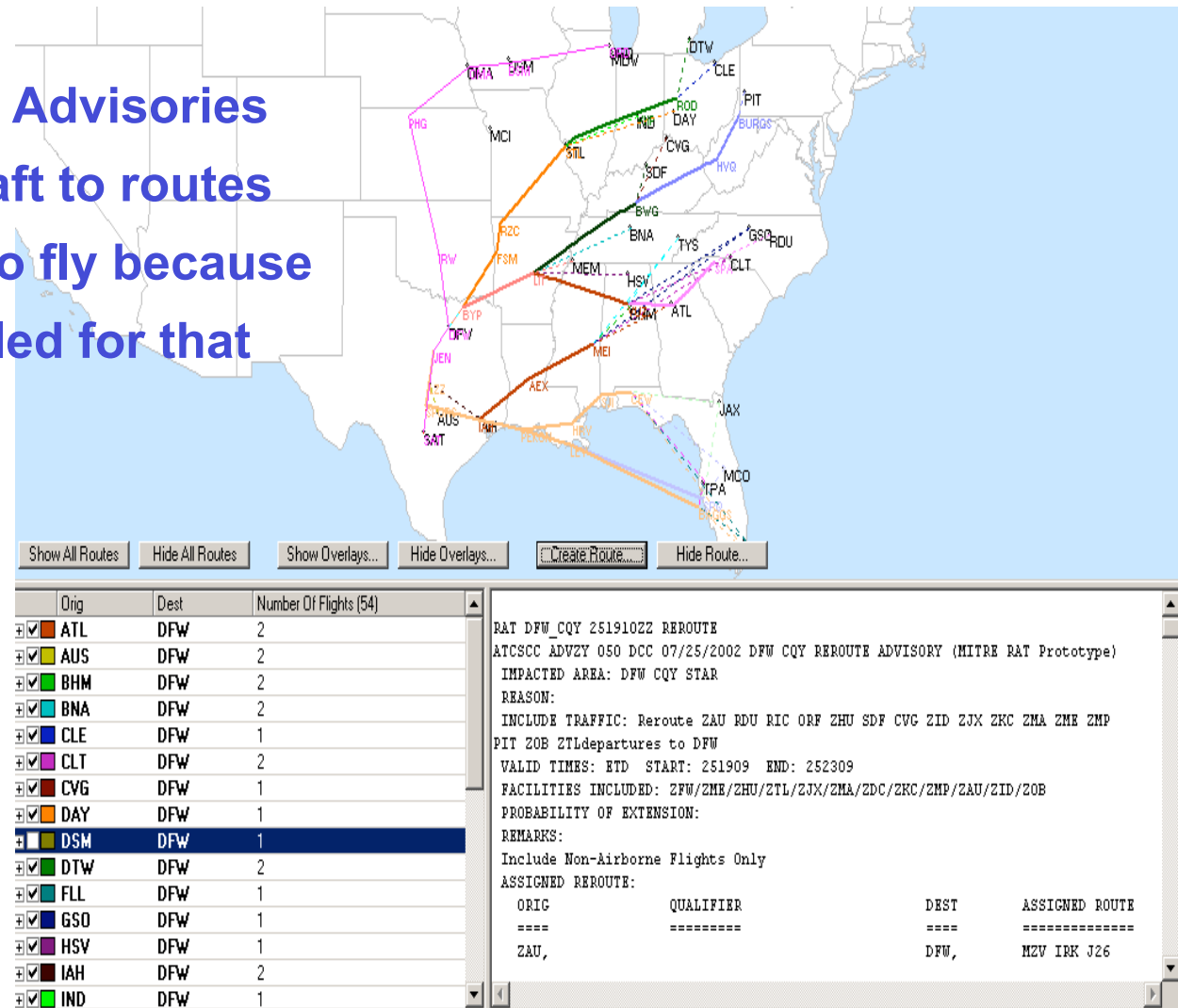
## **Core Idea 3.2: Shared Situation Awareness**

- **The User Triad needs to share the same perspective, or awareness, of weather-related information, so that the best strategy for mitigating weather effects can be communicated and coordinated**
- **Shared awareness can be accomplished through both a common view and a remote perspective view**
- **Users must have quick and easy access to this shared mode**
- **A secure NAS state/weather information distribution network and a unique user interface concept are required**

## Core Idea 3.3: Accommodate NAS User Goals/Constraints

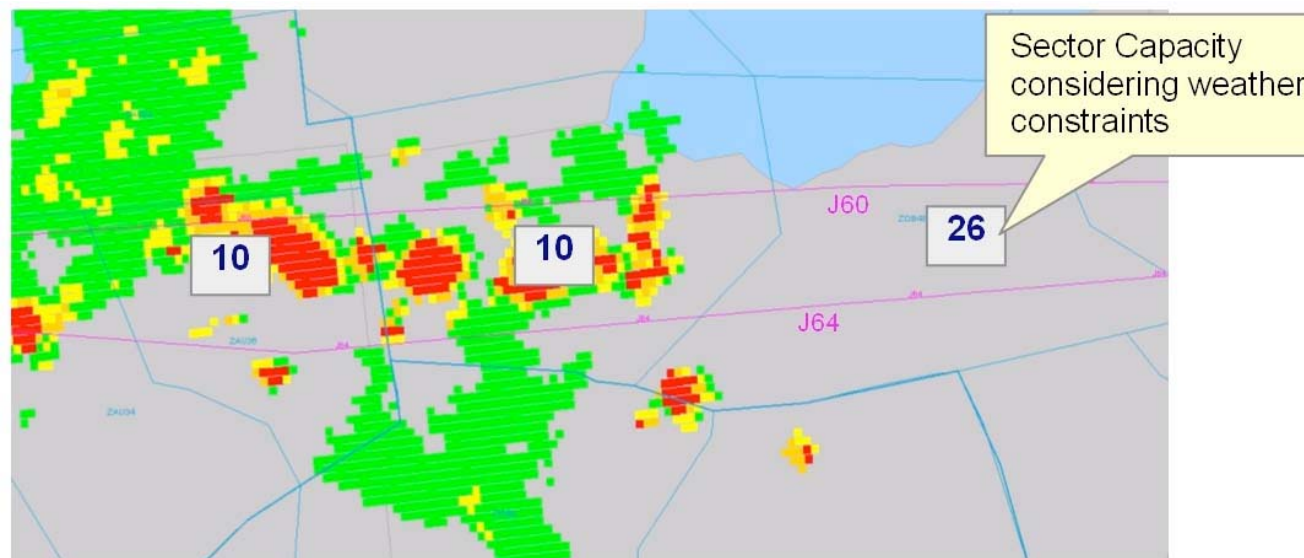
- **Weather Reroute Advisories** that assign aircraft to routes they are unable to fly because they can't be fueled for that long a route

- E.g., An F100 cannot fly a major reroute DFW to ORD (pink route on the left on map)



# Challenges Ahead

- **Integration of Concepts** into ACES Simulation Environment
- **Extension of Concepts** – e.g., how do you adjust sector capacities when two adjacent sectors have vastly different weather coverage but a common jet route?

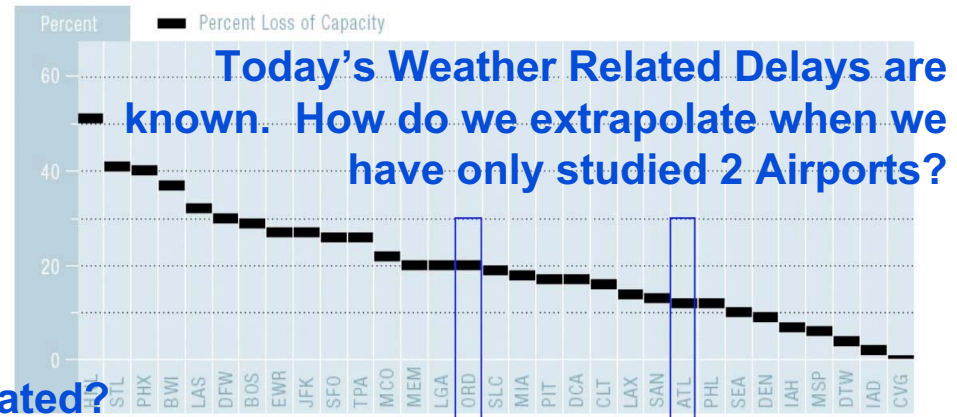
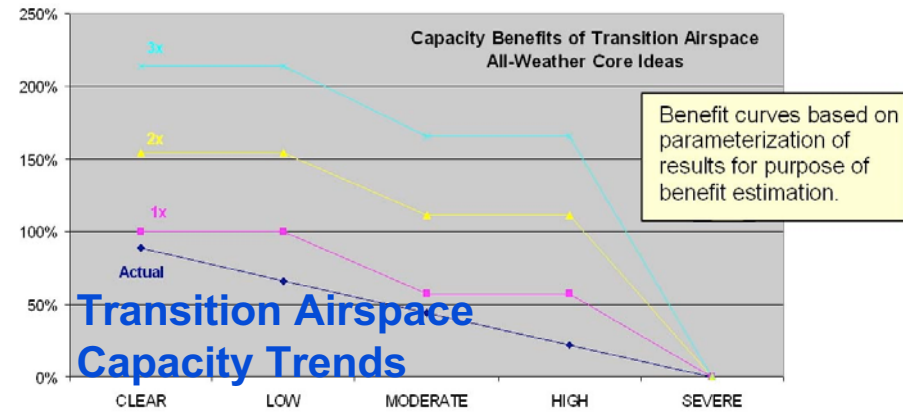
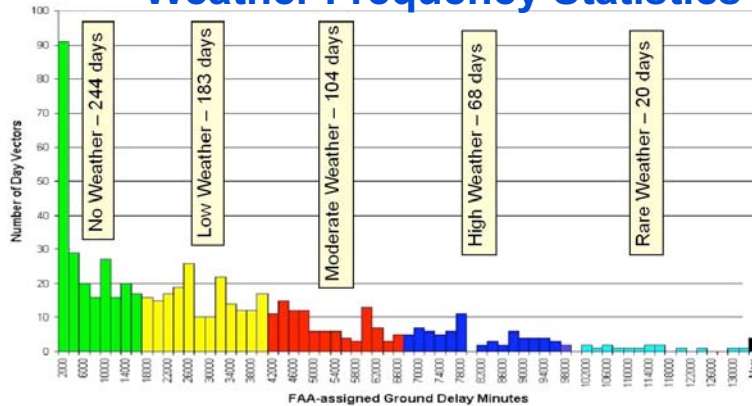


- **TRACON Routes** from single, double, or triple fixes to the runways

# Challenges Ahead

- **Rollup – NAS-Wide Extrapolation with ACES to 2020**

## Weather Frequency Statistics



## Conclusions

- Weather poses **Complex Constraints** that affect each domain of the NAS differently, varying day by day
- **Self Assessment** evaluated Core Ideas on different types of weather (typical, severe, rare) and for 2002 vs. 2020 over all domains of interest
- **Core Ideas** Required to address weather constraints:
  - Flexible Traffic Management Considering Weather Constraints
  - Prediction (Coupled Weather and Traffic Prediction)
  - Coordination and Information Transfer supporting a Shared Situation Awareness

## Point of Contact

